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Comparison of different passive oil-water mixing schemes in a flow loop

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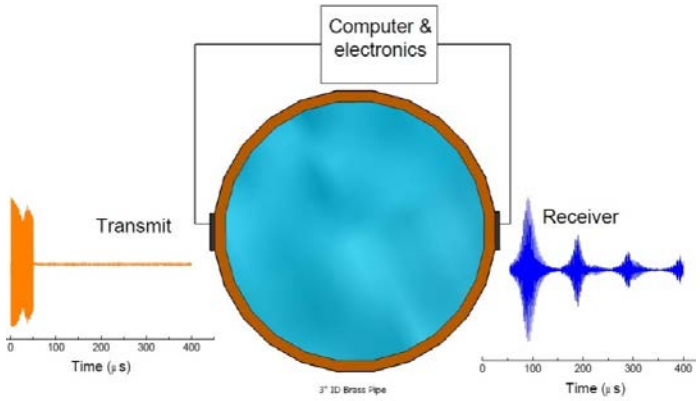
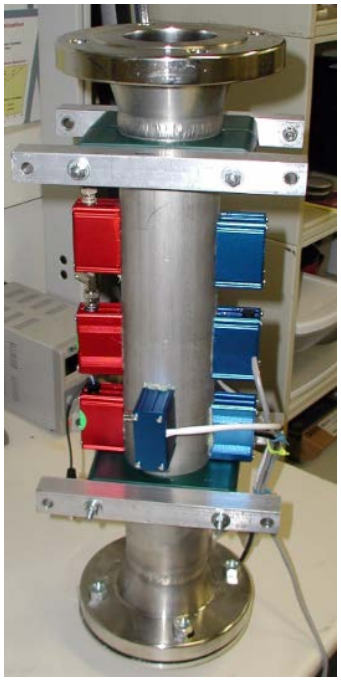
Motivation

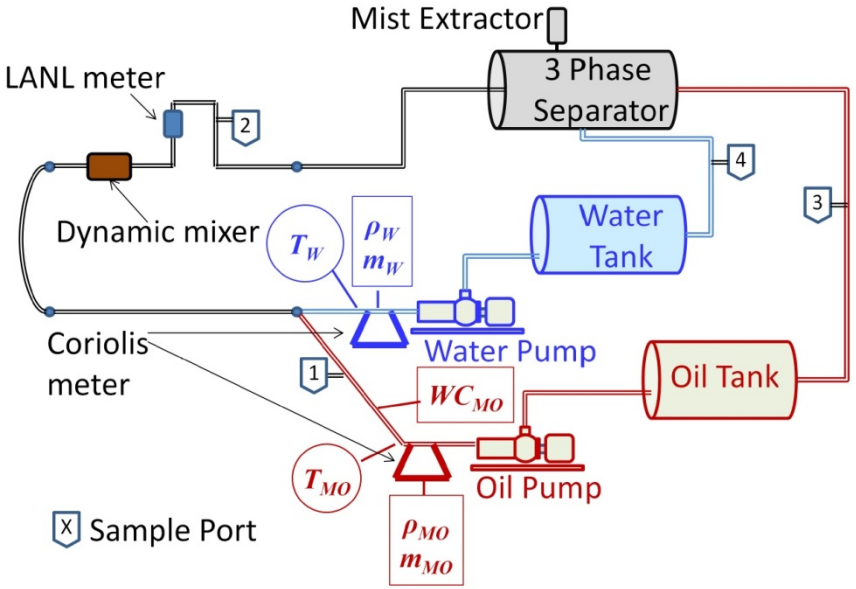
- Non-invasive composition measurement using ultrasound
- Transmitted acoustic signal is modified by fluid
- Process transmitted and received signals
  - Acoustic properties: sound speed, attenuation, density





Chaudhuri et al., ASME J. Fluids Engg, 2012

Controlled flow tests at U-Tulsa

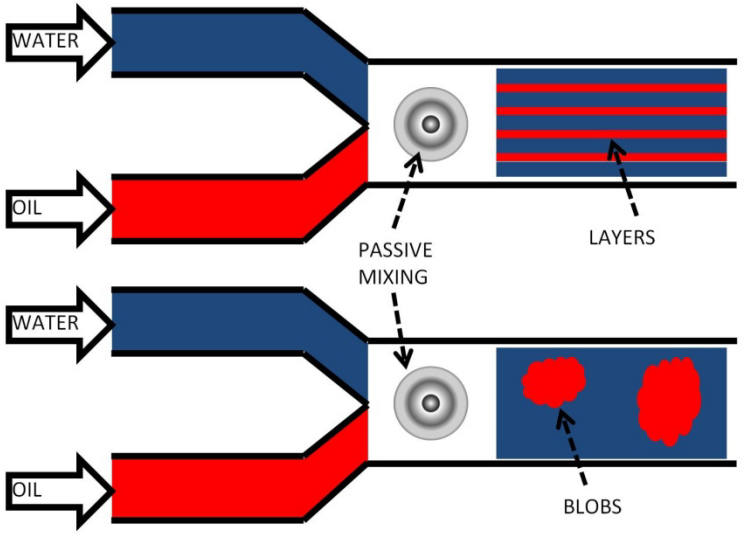


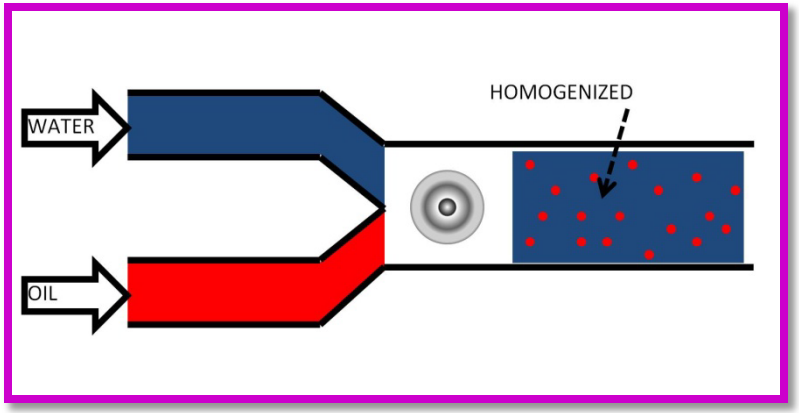
Chaudhuri et al., ASME J. Fluids Engg, 2014

- Proving tests for LANL measurement technique
- Ability to vary flow rate and composition
- Evaluate different scenarios from a test matrix

Lessons learnt

- Lack of proper mixing of two immiscible fluids – oil and water
  - Stratification due to separation of phases
  - Big blobs of oil
- Static mixer not completely effective under all test conditions
  - Needs dynamic mixing
  - What works best?

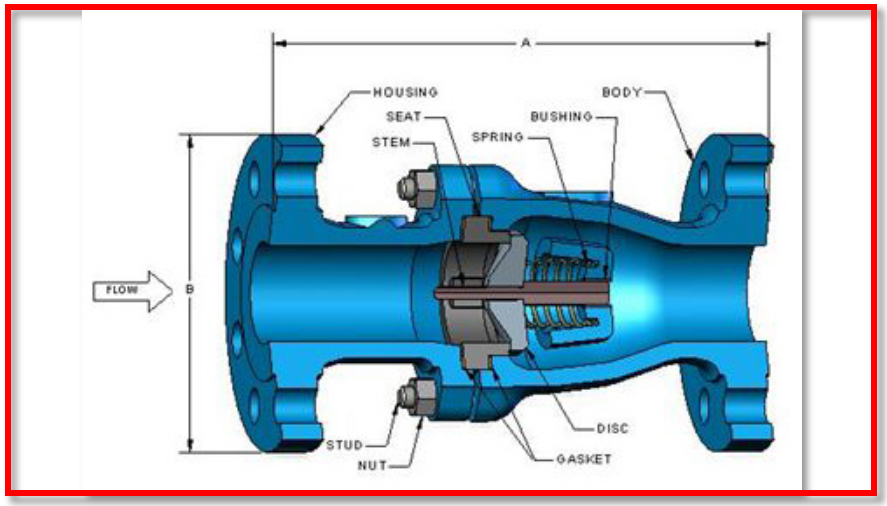




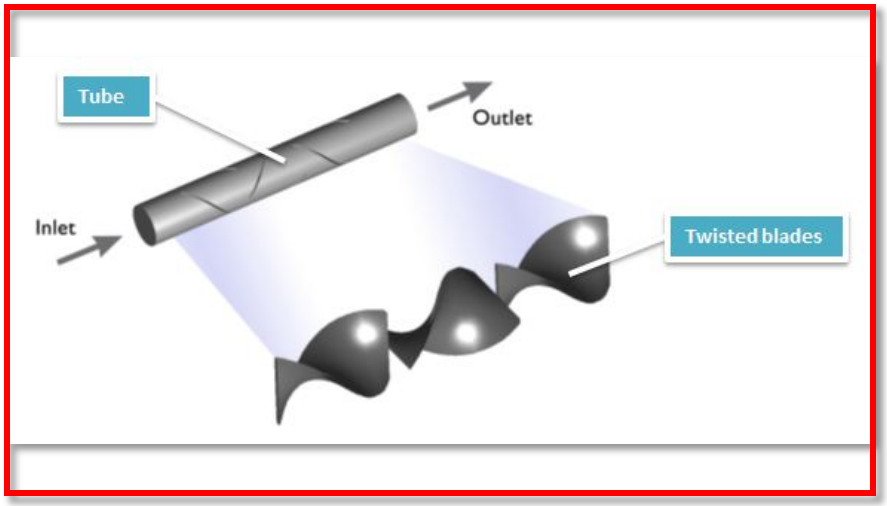
Passive mixing schemes

- Alter flow path by placing obstructions
- Easy to install and operate

BLIND-T



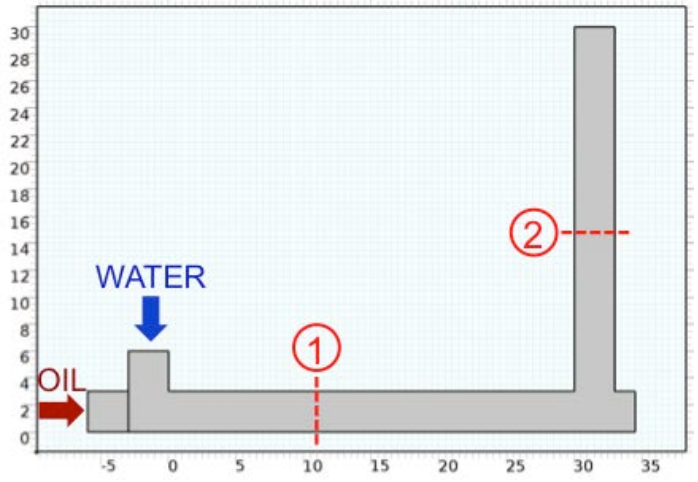
SPRING-LOADED CHECK VALVE

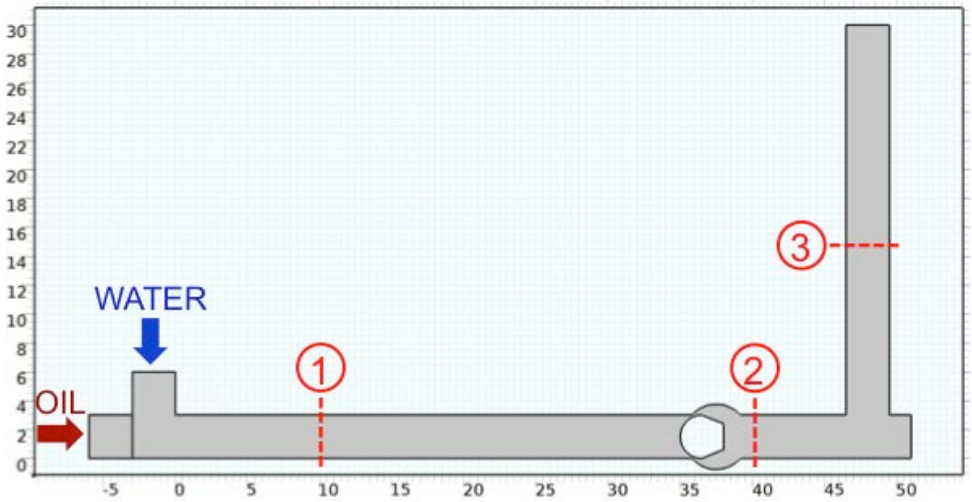


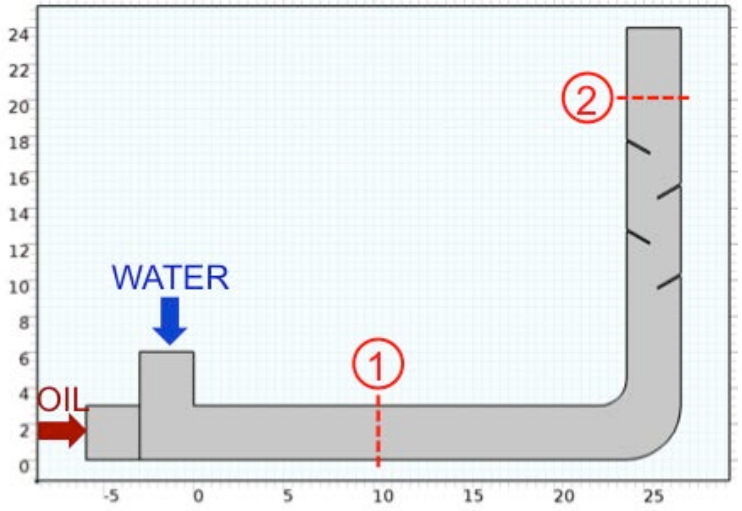
STATIC MIXER

Geometry, properties and inlet conditions

- 3” diameter pipe
  - Water: 1000 kg/m3, 1 cSt
  - Crude oil: 870 kg/m3, 100 cSt
- ϕ: volume fraction of oil
- U_{in}: total liquid velocity
  - Oil inlet velocity = $\phi\, U_{in}$
  - Water inlet velocity = (1-ϕ) U_{in}







Physics

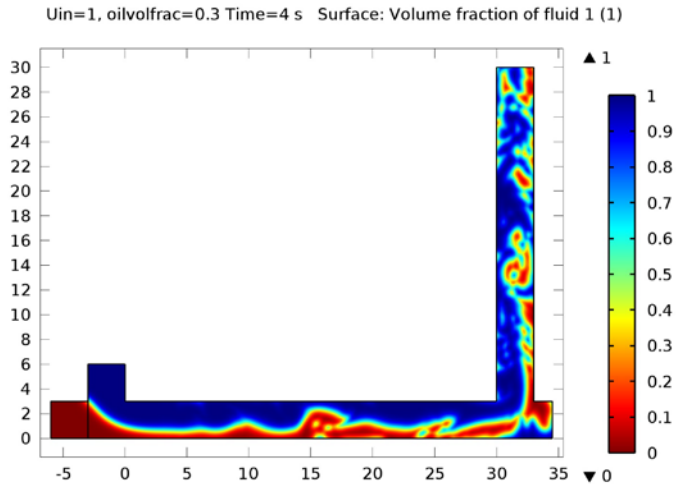
- 2-D Multiphase Flow physics – COMSOL CFD
- Two-Phase Laminar Flow Level Set (*tpf*)
  - Low Reynolds numbers
- Transient solver
  - Capture evolution of flow

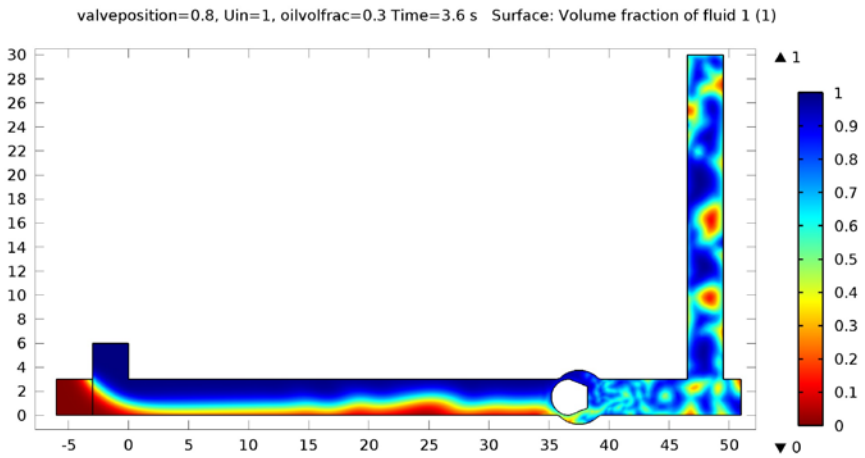
$$\rho\frac{\partial \mathbf{u}}{\partial t} - \nabla\cdot\eta\left(\nabla\mathbf{u} + \left(\nabla\mathbf{u}\right)^{T}\right) + \rho\left(\mathbf{u}\cdot\nabla\right)\mathbf{u} + \nabla p = 0$$

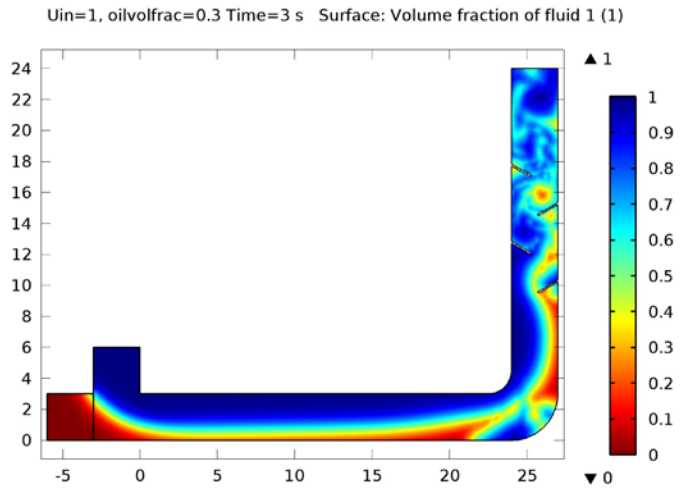
$$\nabla\cdot\mathbf{u} = 0$$

Results

- Distribution of oil and water phases
  - Time evolution
- Lack of homogeneity

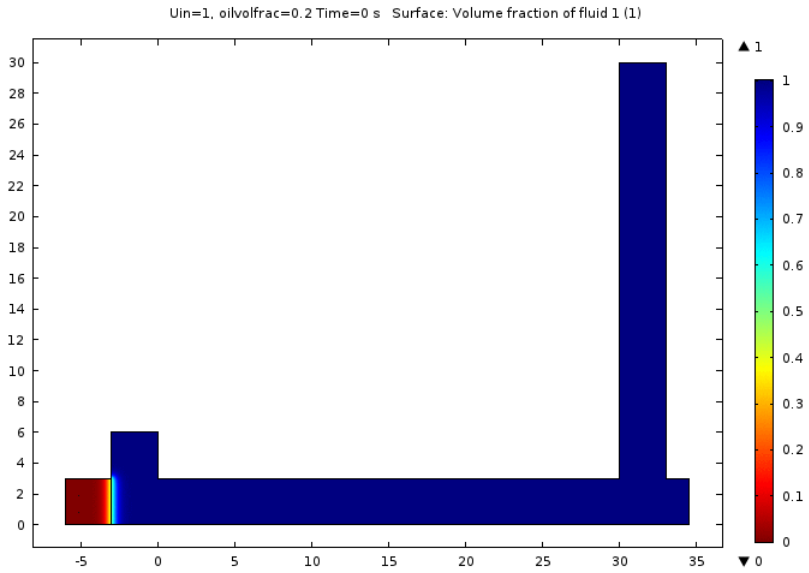




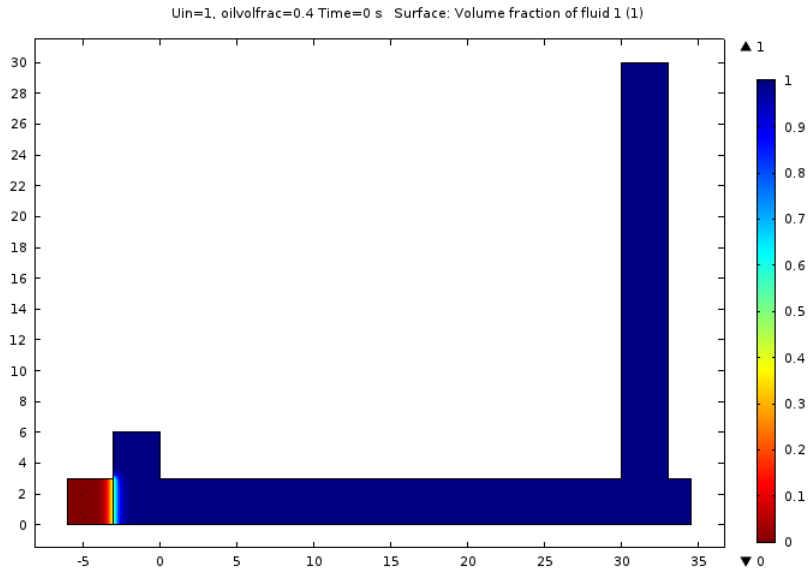


Transient flow – Blind T

$\phi = 0.2$

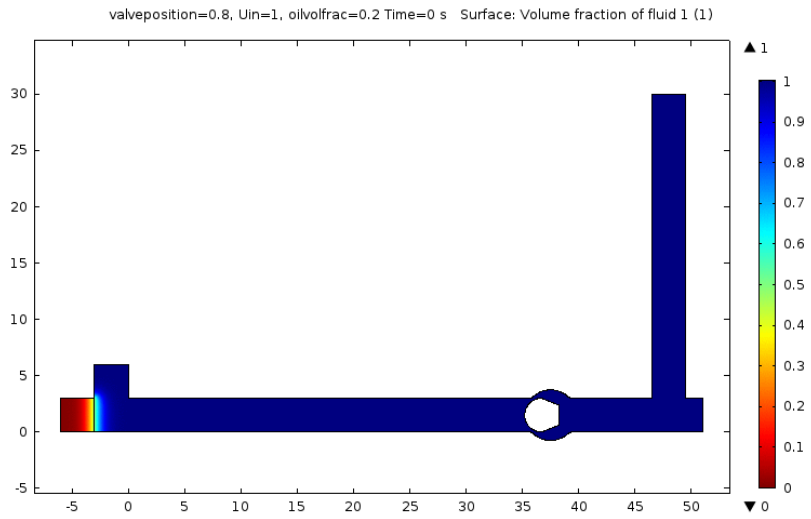


$\phi = 0.4$



Transient flow – Check valve

$\phi = 0.2$



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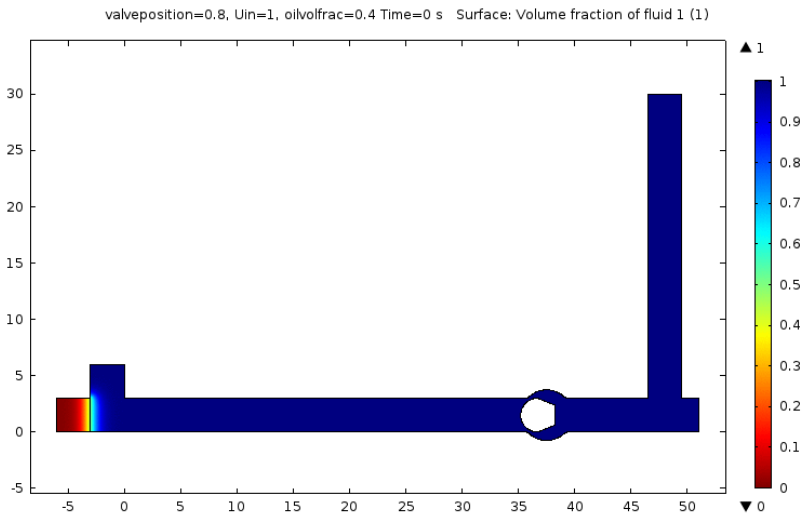
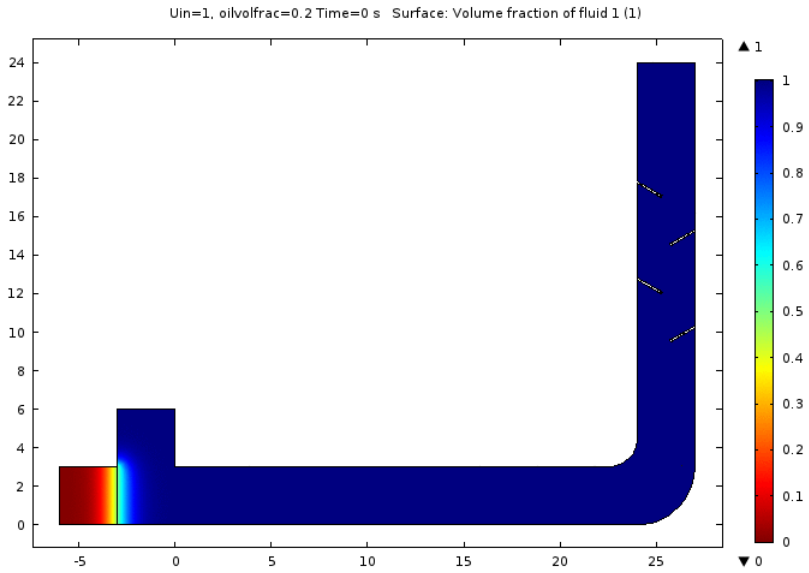


Transient flow – Static mixer

$\phi = 0.2$



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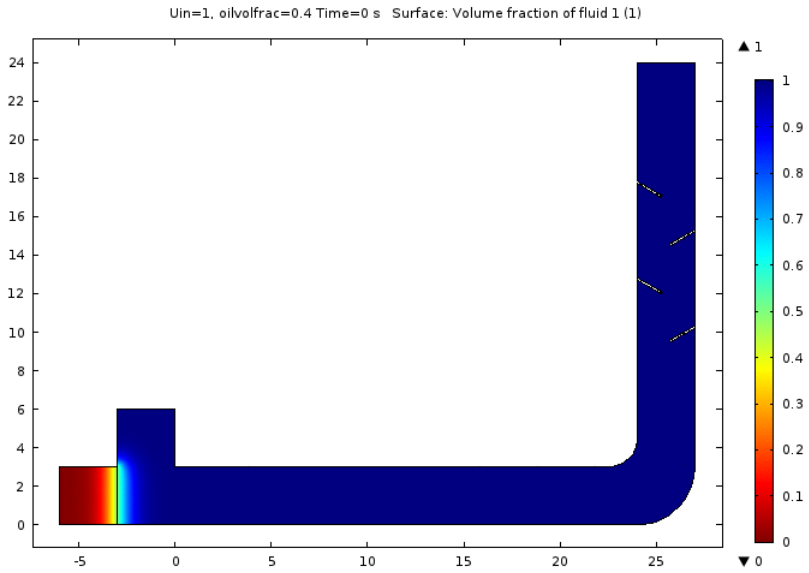
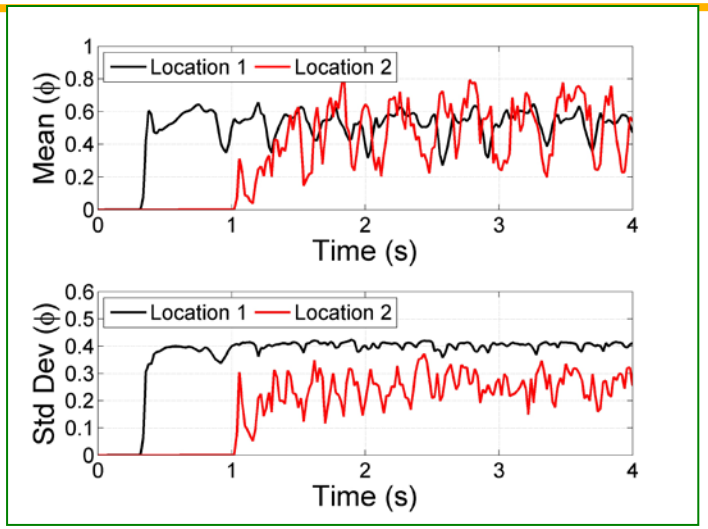
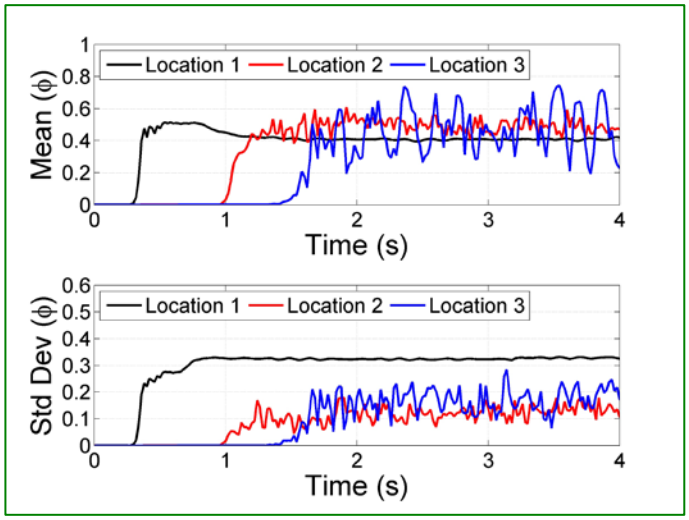


Compare 3 devices: $\phi_{set} = 0.5$, $U_{in} = 1$ m/s

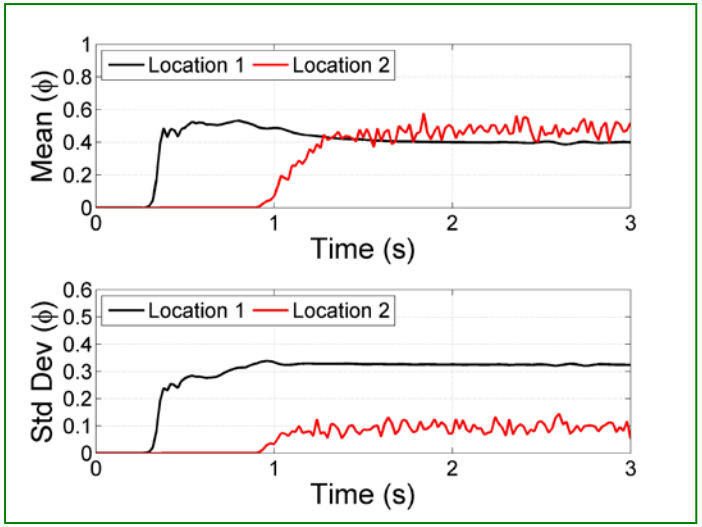
- Mean volume fraction nearly same
  - Mass continuity
- Variation in ϕ is lower downstream of device
  - Homogeneity due to mixing

BLIND-T





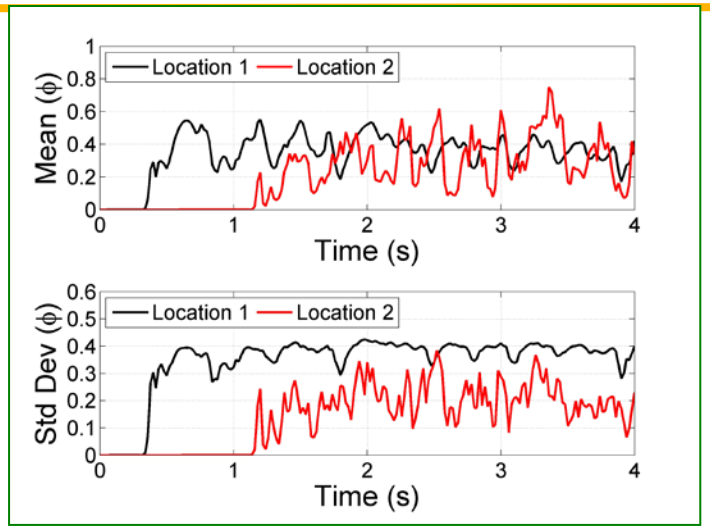
SPRING-LOADED CHECK VALVE

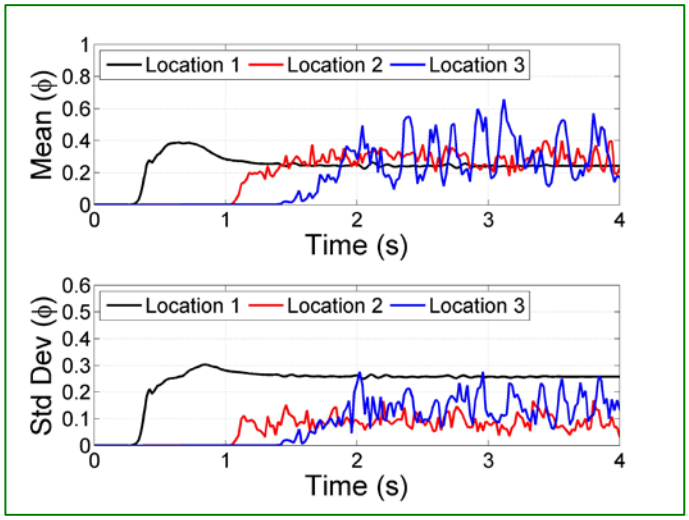


STATIC MIXER

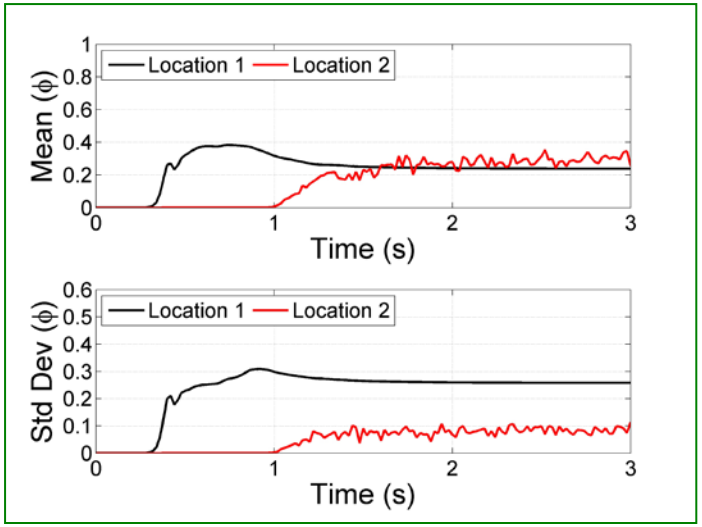
Compare 3 devices: ϕ_{set} = 0.3, U_{in} = 1 m/s

BLIND-T





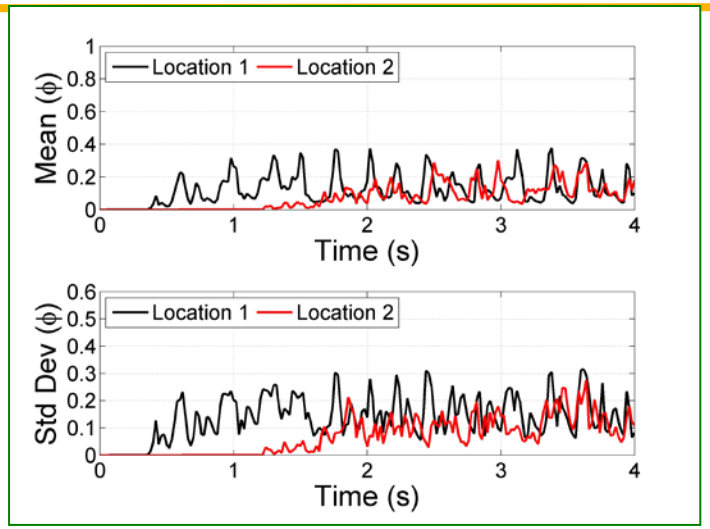
SPRING-LOADED CHECK VALVE

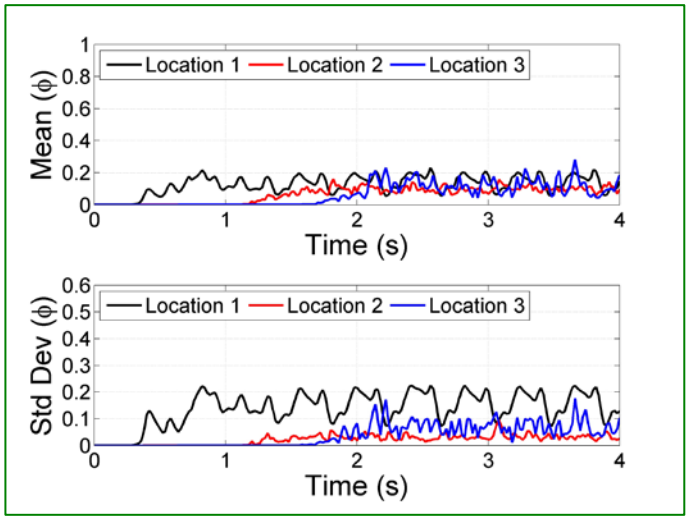


STATIC MIXER

Compare 3 devices: ϕ_{set} = 0.1, U_{in} = 1 m/s

BLIND-T





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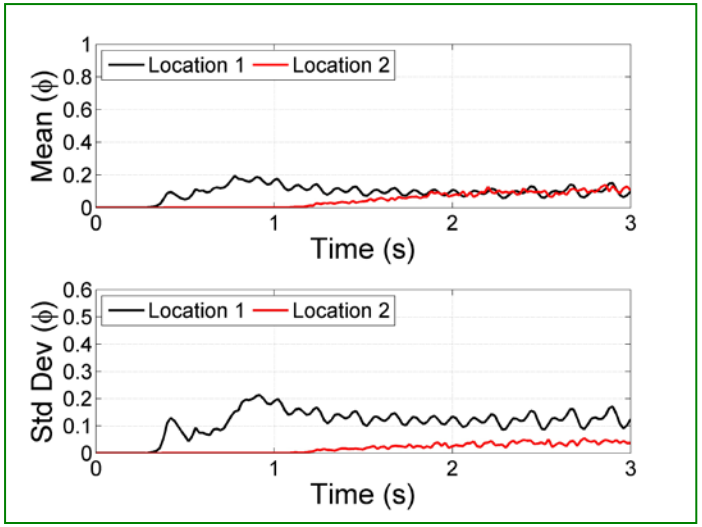

STATIC MIXER

Summary

- Injecting two immiscible fluids into a single pipe does not result in a homogeneous mixture and there are large variations in local properties
- Introduction of passive mixing schemes improves homogeneity of the mixture but their effectiveness depends on physical configuration