Multiphase Flow Conditioning: Industry gaps

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Activities include research on Multiphase Flow and provide technical support for production operations and development within Chevron. Research and projects in the areas of Flow Assurance, Multiphase Flow Conditioning and Compact Separation. Program manager for Chevron's Multiphase Flow Conditioning strategic research program. Leading research conducted at universities and research institutes on multiphase flow. Ph.D. in Petroleum Engineering (2006), University of Tulsa. M.Sc. in Petroleum Engineering (2003), University of Tulsa. B.Sc. Chemical Engineering. (1999). Universidad de Los Andes, Venezuela.

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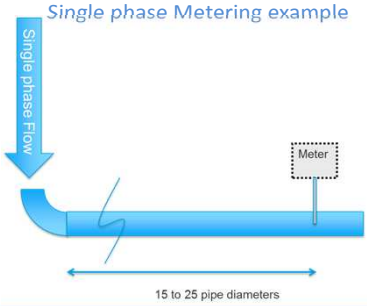
Flow Conditioning

Single phase Metering example



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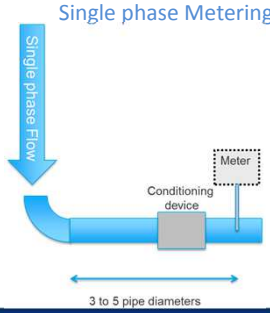
Flow Conditioning

Single phase Metering example



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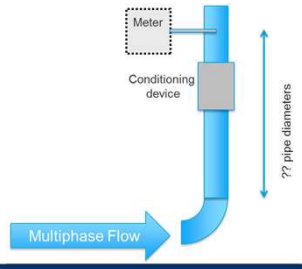
Multiphase Flow Conditioning

Metering example



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Multiphase Flow Conditioning

(Engineered Multiphase Flow, Multiphase Flow Management)

Elements

- MFC typically exists at the intersection of pipeline flow assurance and 1st stage processing and addresses a multitude of issues that are often not considered by FA & process SMEs
- The 2 biggest categories for MFC occur at extreme scales:
  1. Managing flow transients such as surges & slugs
  2. Managing the size and concentration of the dispersed phases which include liquid in gas, gas in liquid, liquid in liquid
- Efficient evaluation of potential solutions requires fundamental understanding of multiphase flow and appropriate models

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Topsides Facilities

Offshore platforms, FPSOs

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Why Multiphase Flow Conditioning?

We can disable a separator by wrongly designing its upstream piping. We need to guarantee its performance

- Gas / Liquid and Liquid / Liquid Flow Conditioning:
  - Droplet / bubble size prediction, coalescence: enable separator operation
  - Improved multiphase flow predictions
  - Reducing breakup of large droplets or bubbles
  - Achieve separation with limited residence time
  - Increase separation performance reliability
  - Reduce over-design
- Multiphase flow split: separation efficiency in parallel processing units
- Mitigate slugging: reduce operational upsets and increase production
- Foam

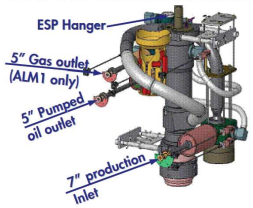
GLCC Subsea Hardware

Parque das Conchas (BC-10) - Shell

Subsea separation

- Integrity, reliability, & maintainability
- Inlet to compact separators
- Upstream effects
- Accessibility

Production Connections to Manifold



Olijnik, L. A., & La Caze, D. A. (2010).

Central Africa - Churn Flow Coalescer:

20" GLCC with 16" Churn Flow Coalescer

Problem

- Improve the efficiency of multiphase separation by conditioning the inlet flow to separators (increase droplet size)

Gaps

- Large diameter, High-pressure
- Developing region, Pipe fittings effect
- Predict residence time required for conditioning (coalescence)

Business Intersect

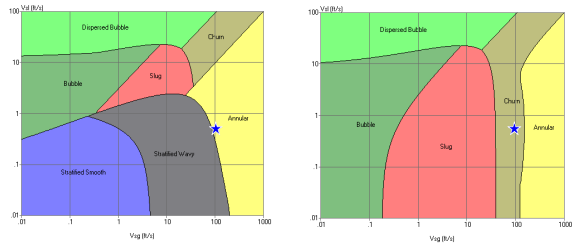
- High GOR applications
- Subsea separation
- Applications to wet gas metering

Before:
No G/L separation;
No liquid level;
No well test balance

After:
Obtained liquid level;
Balanced rates;
Demonstrated value
$6MM in total savings
(vs $150k modifying)

Central Africa - Churn Flow Coalescer:

20" GLCC with 16" Churn Flow Coalescer
Flow pattern maps



0 deg

90 deg

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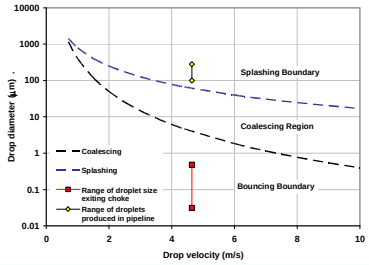
Central Africa - Churn Flow Coalescer:

20" GLCC with 16" Churn Flow Coalescer
Droplet Impact Regime Map



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Technology gaps

- Entrainment is not well predicted
  - Not for liquid/gas, gas/liquid, or liquid/liquid
- Flow developing region upstream of separators inlets
  - Critical for separation performance
  - Data is limited & largely unrepresentative
- Industry's rules of thumb can be grossly misleading
  - Recommended straight pipe length upstream of separators
  - Use of momentum breakers
- Accurate prediction of coalescence or breakup of droplets/bubbles
  - Pipe fittings can produce coalescence or breakup of droplets.

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Entrainment of liquid in gas

Problem

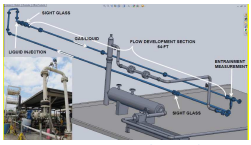
Large uncertainty in calculations of Gas – Liquid Entrainment in oil field applications

Gaps

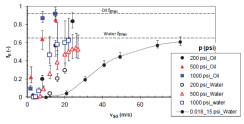
- Large diameter, High-pressure
- Developing region, Pipe fittings effect
- Liquid viscosity

Business Intersect

- High GOR applications (LNG)
- Inclined pipe fatigue analysis due to slugging, erosion, top of the line corrosion, solid transport.
- Applications to wet gas metering



Southwest Research Institute flow loop (Viana, 2012)



Entrainment Fraction (*Mantilla et al, 2012*)

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Slug Mitigation

Problem

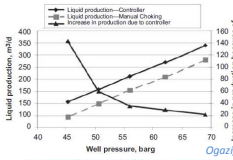
Enhance field production and operability under severe slugging conditions (passive and active techniques)

Gaps

- Map (scale up) operational envelope of mitigation technologies
- Quantify probability of success of a technology proved in the lab
- Solutions "easy" to deploy, especially in brown-field cases

Business Intersect

- Fields with gas/liquid current or future slugging issues



Ogazi, et al (2010).

Makogon, et al. (2011).

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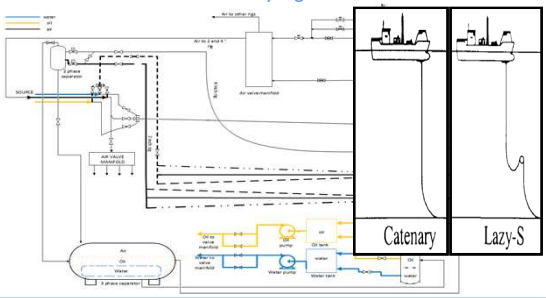
Slug Mitigation:

Cranfield University Rig Overview



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3-phase (Gas / Oil / Water) flow

Problem

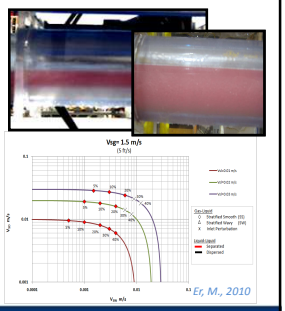
Determine fluid velocities required to prevent free water layer

Gaps

- 3-phase and 2-phase (oil/water) flow experiments for large pipe diameter
- Gas/oil/water flow pattern map models, model for partial water entrainment
- Oil soluble corrosion inhibitor is more effective

Business Intersect

- Pipelines corrosion management, Long Distance Tiebacks
- Managing water influx to limited water handling facilities



Er, M., 2010

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Flow patterns uncertainty

Problem

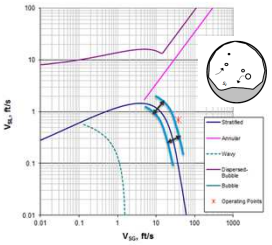
- Multiphase flow modeling assumes sudden changes in flow pattern after crossing transition boundary leading to faulty recommendations

Gaps

- Discontinuity in pressure drop prediction
- Models validation against available multiphase flow pattern data
- Scale up issues

Business Intersect

- Top-of-the-line corrosion
- Fields operating near flow pattern transition boundaries



70% tests, model predicted the flow regime was not stratified flow

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"Conditioning" choke

Problem

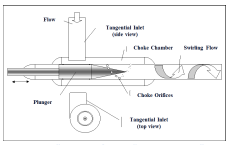
- Large contribution to uncertainty of separation design from upstream devices used to control flow: pressure, flow rate

Gaps

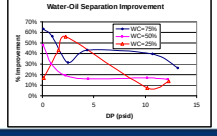
- Conventional" choke:
- High shear stress
- Break up oil/water droplets
- Make oil/water emulsions

Business Intersect

- Fields with oil/water (emulsions) separation issues



"Conditioning" out-performs "Conventional" choke



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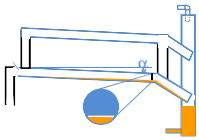
Slug Damper

Problem

- Reduce the fluctuation of liquid flow rate to equipment downstream (instantaneous liquid flow rate during incoming slug can be 10 times average liquid flow rate)



Gaps

- Predictions in terrain slugging length and frequency
- Slug dissipation length prediction

Field Installation of Slug Damper: Indonesia

Business Intersect

- Fields with Terrain slugging issues

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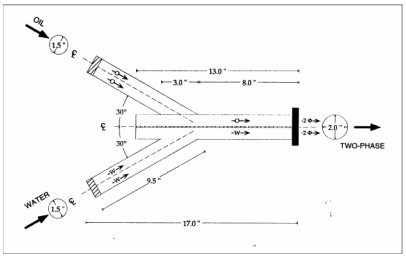
Liquid-Liquid Developing Flow Region

Schematic of Trallero (1995) Inlet Mixer



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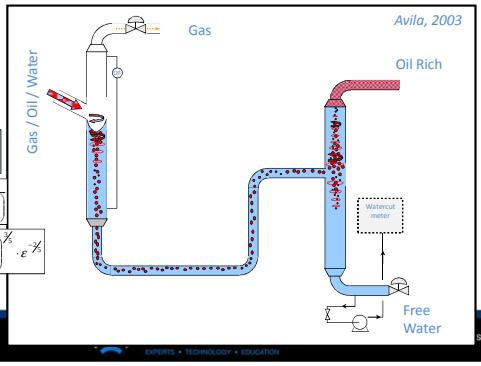
Three-Phase Compact Separators



$$\bar{\varepsilon} \simeq \frac{\Delta P_{perm} \cdot U_o}{\rho \cdot L_{dis}}$$

$$We_{crit} = \frac{24}{\pi^2 \left(\frac{3 \cdot \rho_m}{\rho_c} + 2\right)}$$

$$d_{max} = We_{crit}^{3/5} \cdot \left(\frac{\sigma}{\rho_c}\right)^{3/5} \cdot \varepsilon^{-2/5}$$

Janssen (2001)

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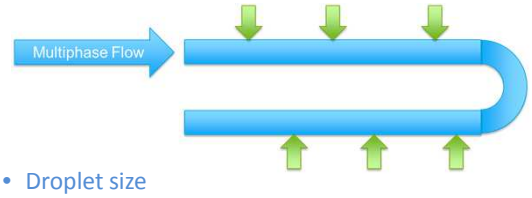
Measurements in developing region

Straight pipe versus tortuous path



- Droplet size
- Volume fraction of each phase
- Velocity profiles

Measurements f (x,t)

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Technology risks

Risk	Mitigation
Experiments and Models conducted and validated in **small scale vs. large scale** field conditions	Compile field data, conduct experiments in high pressure facilities, conduct field trials (safe conditions), capture scaling laws and phenomena in models for wide application
Meet expectations: models **predict expected improvement** in performance	Validation of model predictions, successful field trials, challenge models both in-house and commercially available with difficult field cases
Characterization of **uncertainty**	Establish uncertainty in a confidence envelope that may be needed in a decision analysis in weighing competing technologies

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Way Forward

- Consider collaboration with different companies to close gaps in Multiphase Flow Conditioning
- Propose a session dedicated to Multiphase Flow Conditioning in an upcoming SPE conference, workshop or forum
- Creation of a new page for “Multiphase Flow Conditioning” in SPE’s PetroWiki
- Emphasize importance of current TUFFP projects related to Multiphase Flow Conditioning or consider the need of a parallel JIP specialized on these kind of projects

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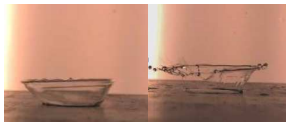
Thank you



Water Droplet and Oil Droplet against Oil Coated Metal
Courtesy The University of Tulsa

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