THE UNIVERSITY OF TULSA

Hydrates Flow Performance Project

Advisory Board Meeting

Gallery
Allen Chapman Activity Center (ACAC)
E. 5th Place & S. Gary
Tulsa, OK 74104

AGENDA

Thursday, November 8, 2007

SUNRISE BREAKFAST.....8:00 a.m.
Gallery ACAC

Mike Volk..... 8:45 a.m. - 9:00 a.m.
Introduction

Risk Assessment Summary

Emmanuel Delle-Case..... 9:00 a.m. - 9:40 a.m.
Steady State Experiments

Ramon Domingues/ Emmanuel Delle-Case.....9:40 a.m. - 10:10 a.m.
Steady State Simulations

BREAK ..... 10:10 a.m. - 10:25 a.m.

Emmanuel Delle-Case..... 10:25 a.m. - 10:40 a.m.
Transient Experiments

Angelina Colleta.....10:40 a.m. - 11:00 a.m.
Jumper Study
Visualization Studies with High Speed Video Technique

Droplet/Hydrate Particle Distributions

Alisher Yunuskhojayev..... 11:00 a.m. - 11:20 a.m.
Dispersion Properties w/o Hydrates

Rene Sanchez Torres..... 11:20 a.m. - 12:00 p.m.
Water Droplet Size and Their Effect on Plugging Tendencies

LUNCH.....12:00 p.m. - 1:00 p.m.
President's Formal Lounge

Dissociation/Plug Properties

Lissett Barrios.....1:00 p.m. - 1:45 p.m.

Plug Characterization Study
Dissociation Model Results

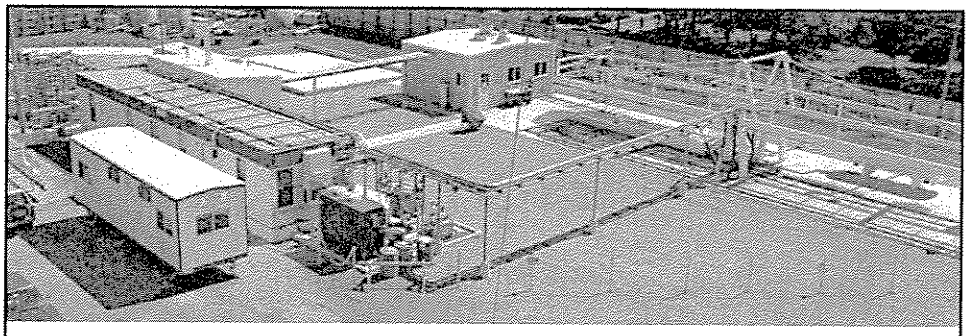
Mike Volk

Phase III Path Forward.....1:45 p.m. - 2:00 p.m.

Mike Volk..... 2:00 p.m. - 2:15 p.m.

Open Discussion/Issue Bin

Closing Remarks/Adjourn .....2:15 p.m.



Tulsa University
Hydrate Flow Performance JIP

10th TUHFP Advisory Board Meeting

November 8, 2007

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Welcome

- 10th Semi-Annual Advisory Board Meeting
- Handouts
  - Brochure, Slide Copy Book and CD
- Sign-Up List
  - Please leave Business Card at Registration Table

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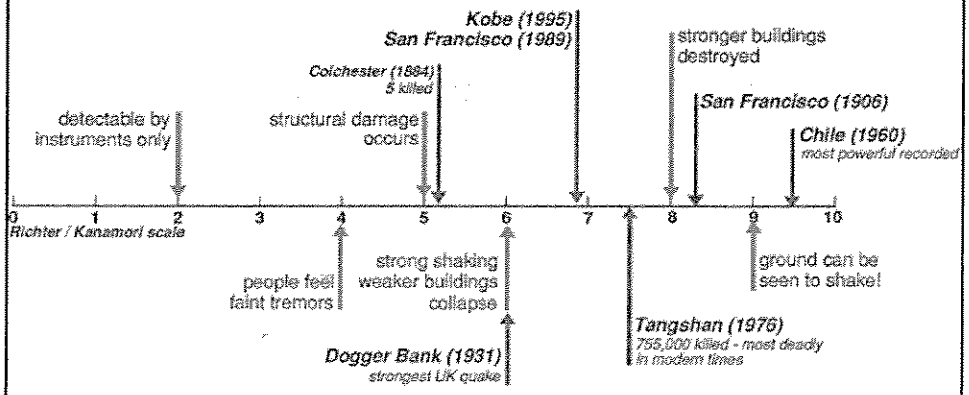
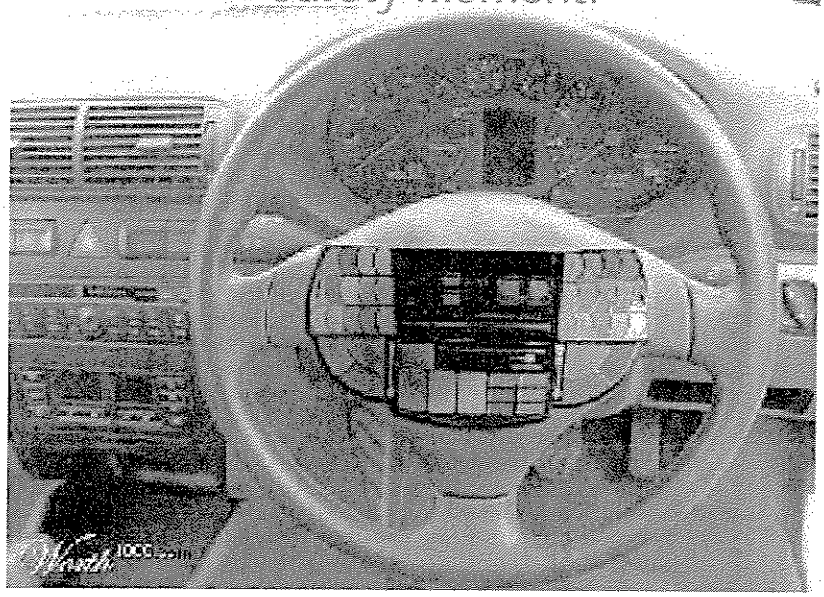
Please Put Your Cell Phone to Silent

Earthquakes



Safety Moment!



Emergency Information

- Emergency Exits
- Assembly Point
  - Grassy area on Northwest side of ACAC
- Tornado Shelter Area
  - Level 1 Restrooms, stairwells, Room 115
- Campus Emergency
  - Call 9-911
  - Campus Security ext 5555 or 918-631-5555
  - Primary Emergency Response
    - Al Soltow ext 2766, 918-631-2766 or 918-607-1830
- Rest Rooms

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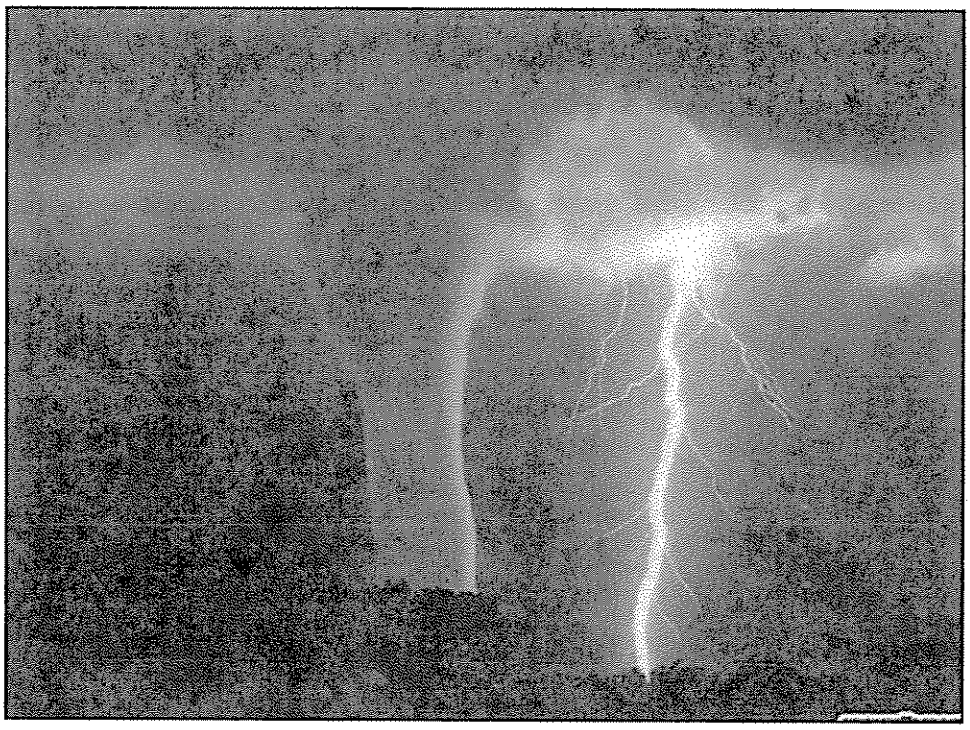
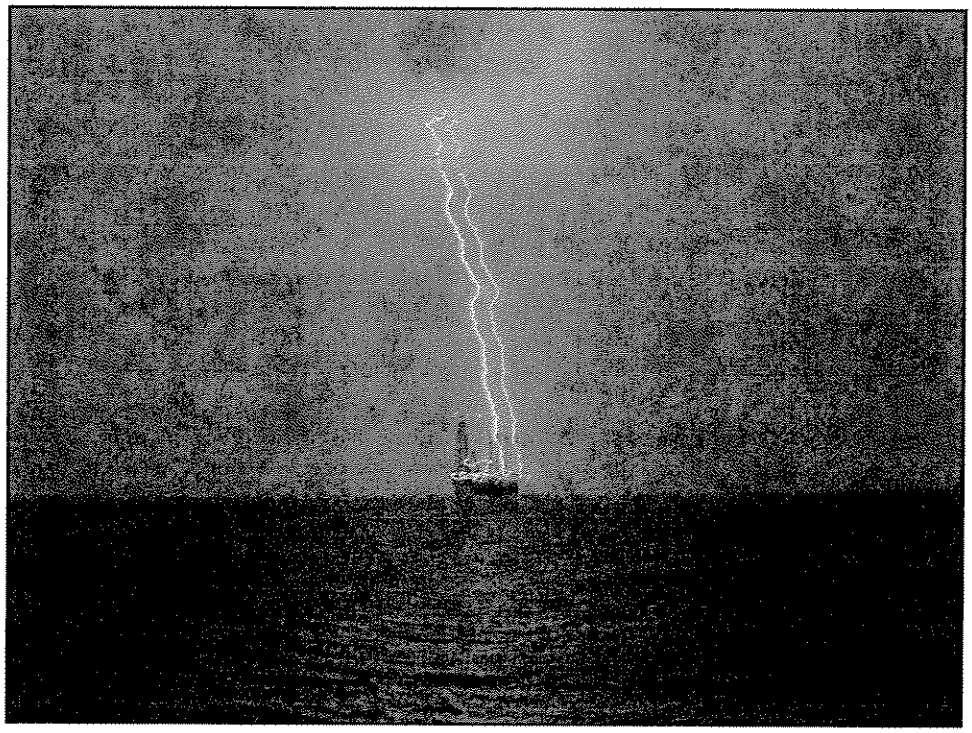
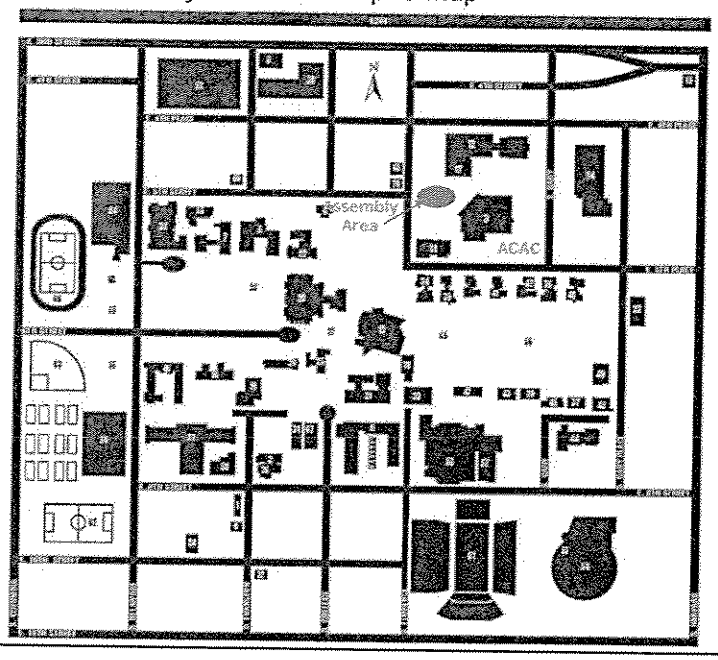
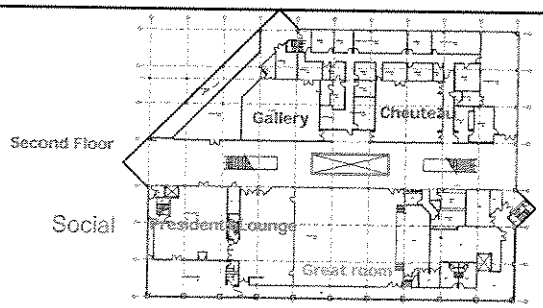


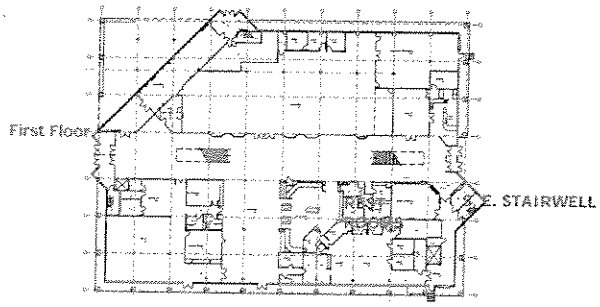


The University of Tulsa Campus Map

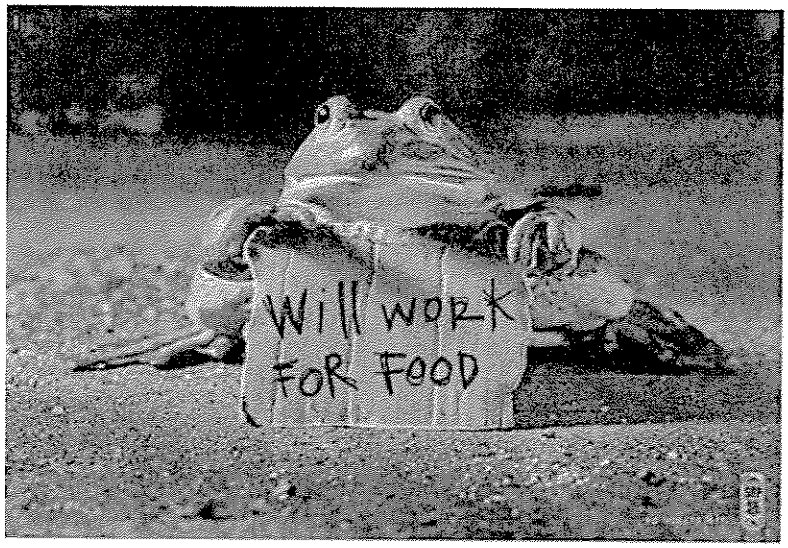




Allen Chapman Activity Center



Staff Additions



Hydrate Staff

- Mike Volk – PI
- Emmanuel Delle-Case, Cem Sarica, & Keith Wisecarver &– Co-PI's
- Giorgio Geraci – Post Doc
- Lissett Barrios – Post Doc
- Jose Aramburu – Operation Engineers
- Garrett Pierce – Technician
- Douglas Estanga, Rene Sanchez Torres, Ashutosh Kak, Alisher Yunuskhodzha, Ramon Domingues, Angelina Colleta & Kieran Barrows – Graduate students
- Lori Combs – Project Coordinator
- Justin Horn – Web Site Administrator

ABM Agenda

Risk Assessment Summary

Emmanuel Delle-Case.....9:00 a.m. - 9:40 a.m.
Steady State Experiments

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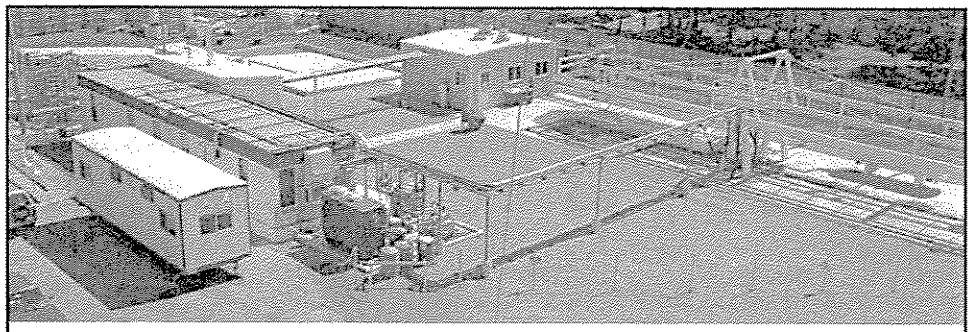

Hydrate Cold Flow Performance Program

Activity Summary

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Objectives

- Better understanding of the importance of fluid and operating parameters on plugging tendencies
  - Establish a "safe" operating envelope
- Better understanding and management of risk for shutdown and restart of production systems
- Better understanding of the impact of AA concentration on plugging tendency and pressure drops
- Develop dissociation and slurry flow models
- Completion status: 95%

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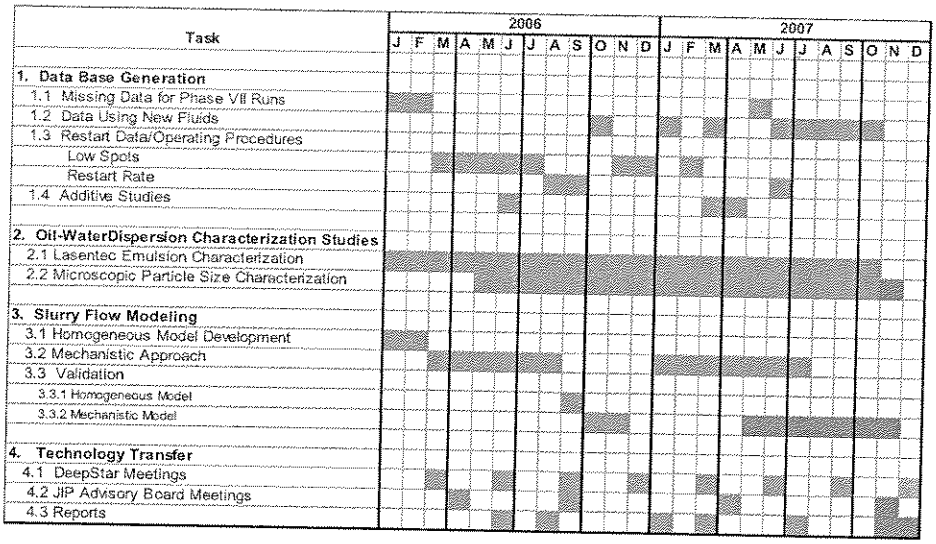
Completion Status



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Completion Status

Fluid	Proposed		Completed
NG/Dodecane	11		5
Citgo	15		40
Troika	7		10
Buttermilk	7		10
Caratinga	7		22
Conroe	21		12
Blake	4		2
Total	72		101

Flow loop Tests

- 101 Tests completed through October 1st
  - 140%
  - 88 Constant P and 13 Constant V
  - Types: parametric, restart, additive & slurry flow

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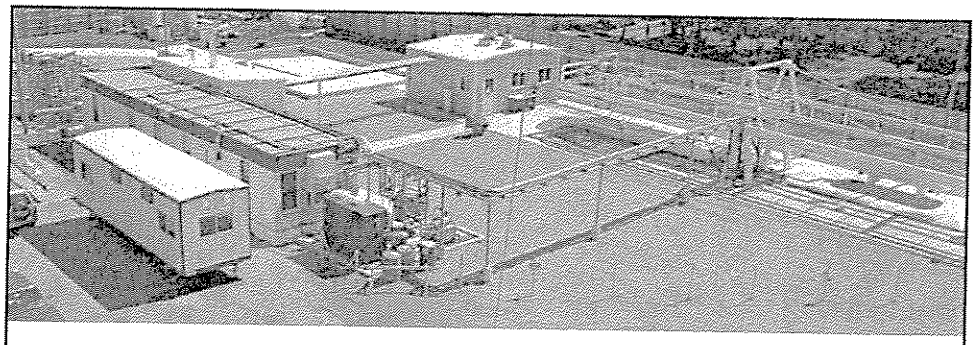
Completion Status

- Dispersion Characterization Studies
  - Dispersion properties and droplet size linked to plugging tendencies
  - High pressure sampling system successfully tested
    - Reproducible results obtained
  - At rest, droplets coated with hydrate film
  - Under shear conditions
    - Snow-like
    - Non-spherical particles, flakes…
  - Droplet break-up believed to be a key mechanism in agglomeration

Completion Status

- Modeling Efforts
  - Slurry Flow Model
    - Dispersed & stratified conditions
    - Needs slug flow model
  - Dissociation Model
    - Fit for homogeneous plugs very good
    - New model development begun
  - Began development of a flow loop simulator with PVTSim open-structure



Steady-State Experiments

Emmanuel Delle-Case

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Outline

- 18 additional experiments
  - 9 Conroe
  - 3 Troika
  - 2 Caratinga
  - 2 Citgo 19 – Additive
  - 2 Blake
- Effect of variables
- Future work

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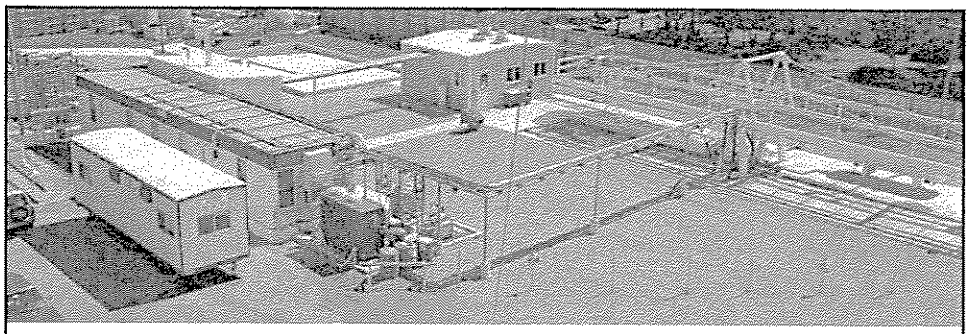

Conroe / Troika / Caratinga Experiments

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Conroe Test Matrix

Test #	Liquid loading (% Vol.)	Water cut (% Vol.)	Pump speed (rpm)
CO-01	50	25	Rocking
CO-02 (1)	50	25	250
CO-03 (1)	50	25	750
CO-05	50	25	750
CO-06			1250
CO-11		37.5	500
CO-10			750
CO-12			1250
CO-08		50	750
CO-09			1250
CO-07	75	25	1250

(1) *Rupture disk ruptured - Uncontrolled velocity*

250 rpm = 0.6 ft/s
500 rpm = 2.2 ft/s
750 rpm = 3.9 ft/s
1250 rpm = 7.2 ft/s

Troika / Caratinga Tests

Troika

Test #	Liquid loading (% Vol.)	Water cut (% Vol.)	Pump speed (rpm)
TR-24	50	37.5	500
TR-23			750
TR-22	75	25	1250

Caratinga

Test #	Liquid loading (% Vol.)	Water cut (% Vol.)	Pump speed (rpm)
CA-31	75	25	750
CA-30			1250

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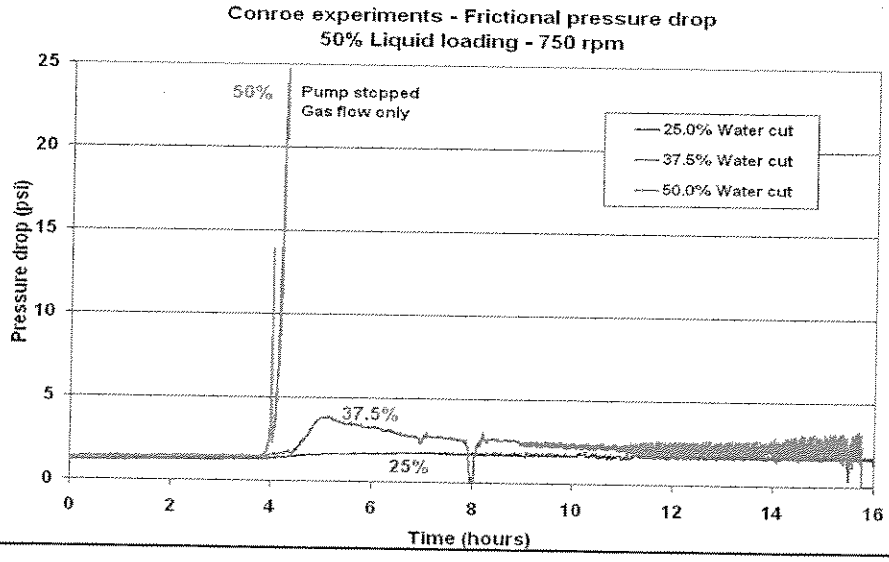
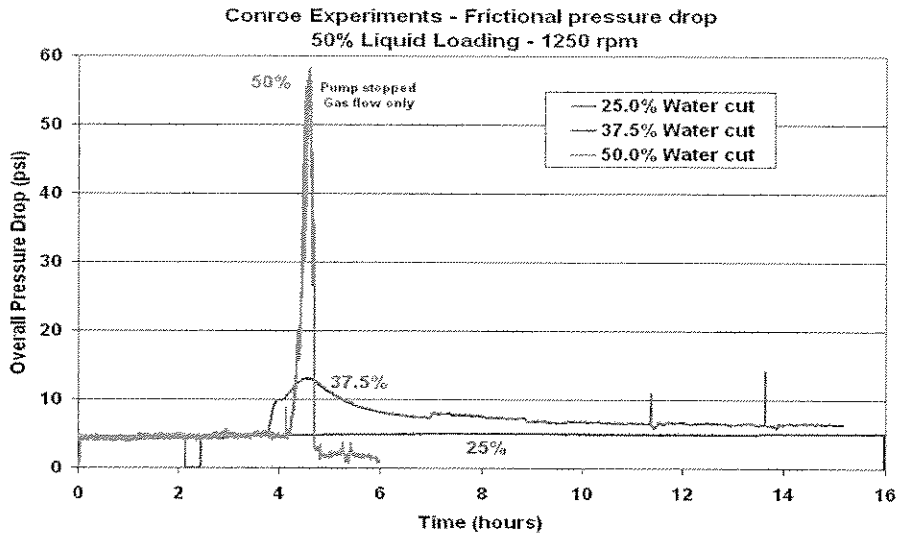
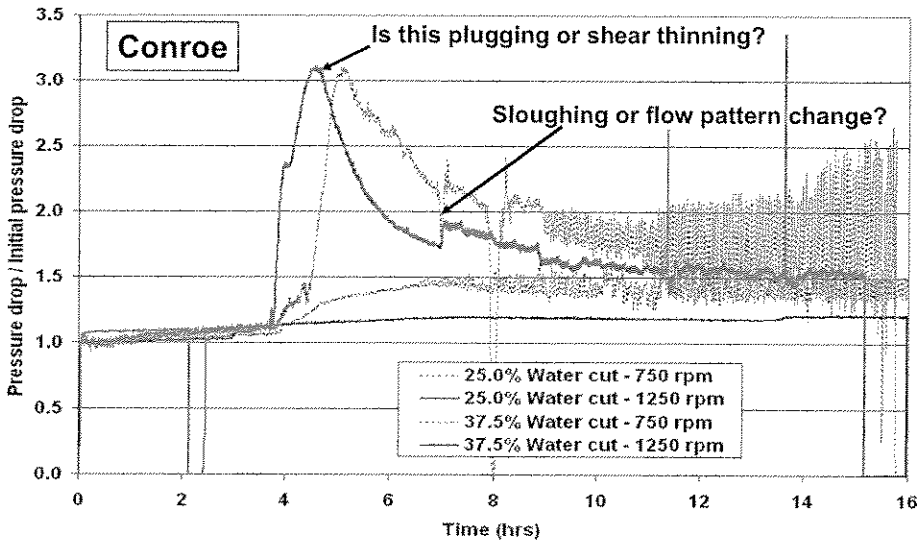
Effect of Water Cut (3.9 ft/s)



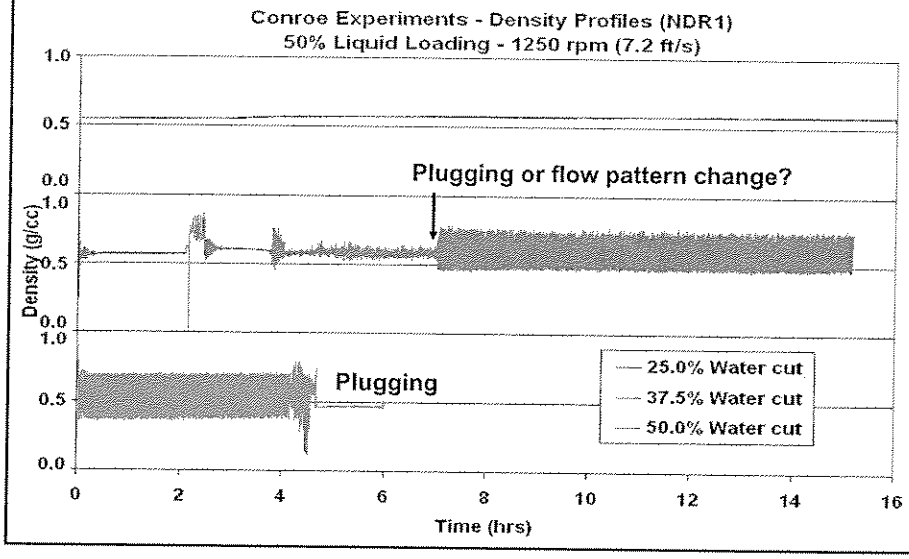
Effect of Water Cut (7.2 ft/s)



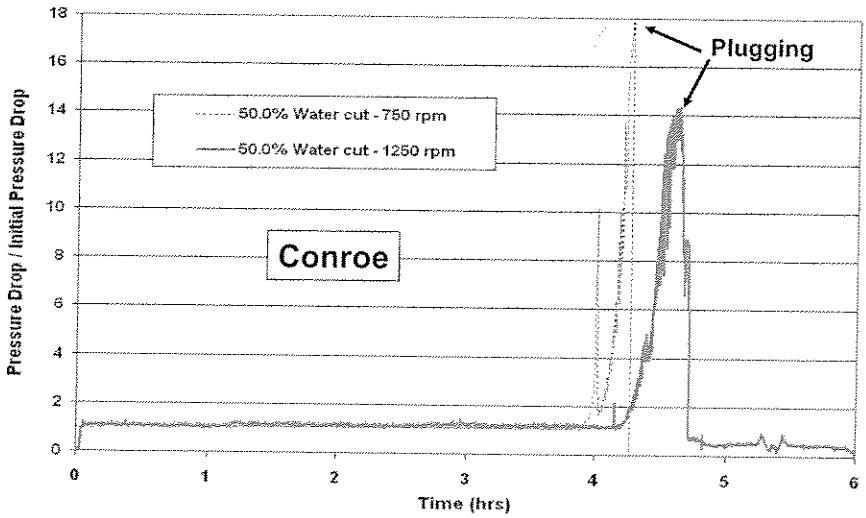
Effect of Water Cut



Sloughing or Flow Pattern



Effect of Water Cut



Effect of Water Cut

- Water cut increases plugging
  - 25%: Slurry flow
  - 50%: Severe plugging
  - Difficult to estimate for intermediate water cuts
- Plugging mechanism
  - Seems to be solid bed formation at the bottom of the pipe
- Change in velocity did not affect outcome
  - From 3.9 ft/s to 7.2 ft/s

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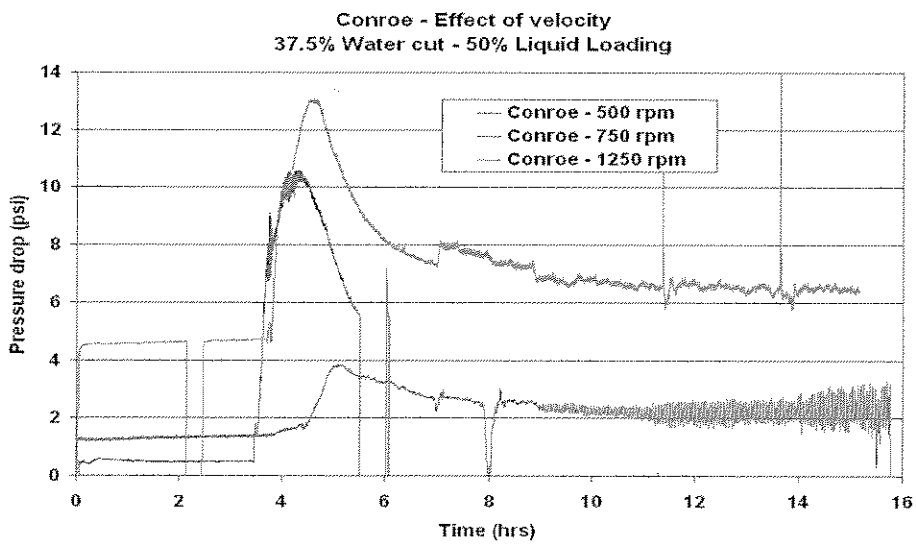
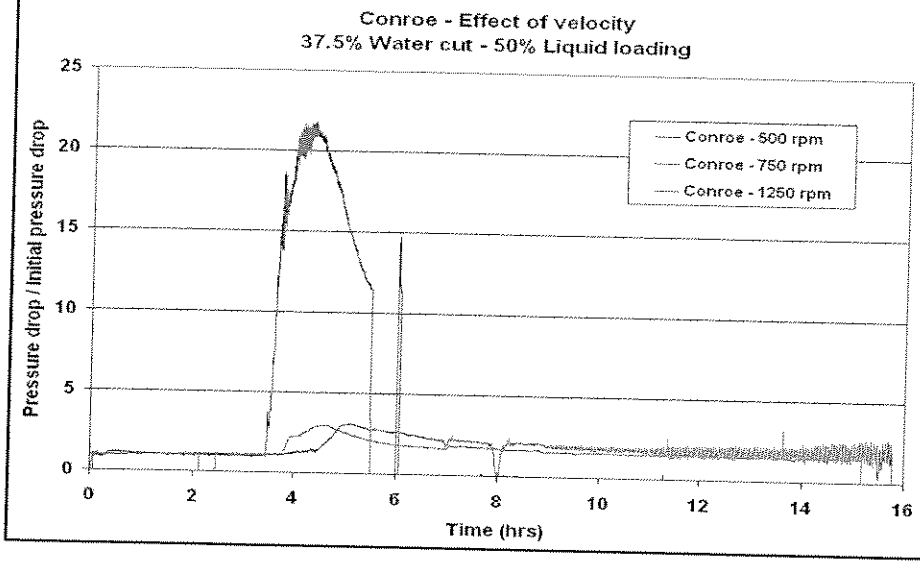
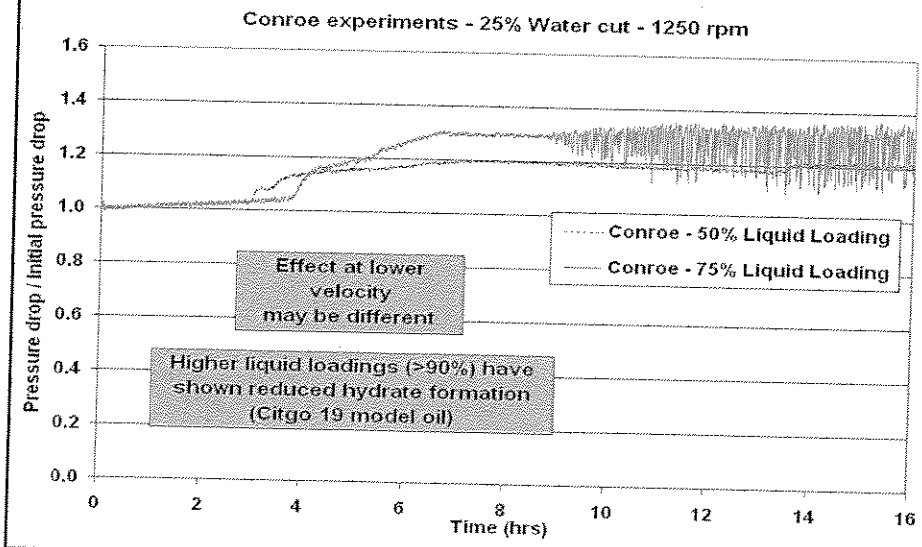
Effect of Velocity



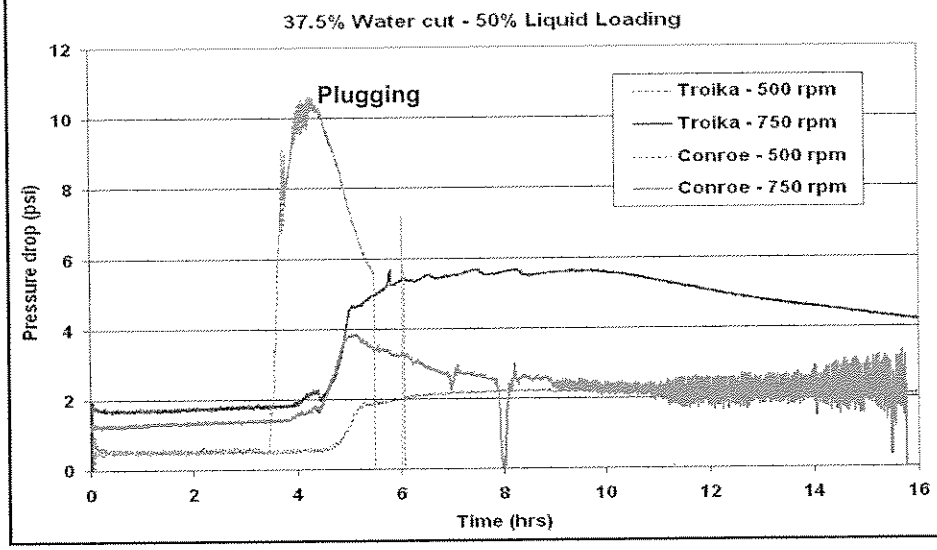
Effect of Velocity



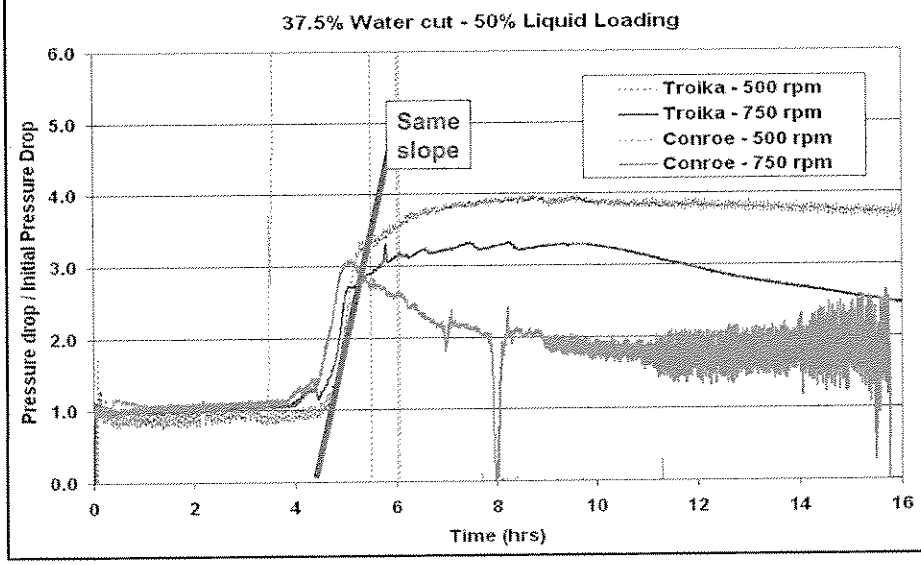
Effect of Liquid Loading



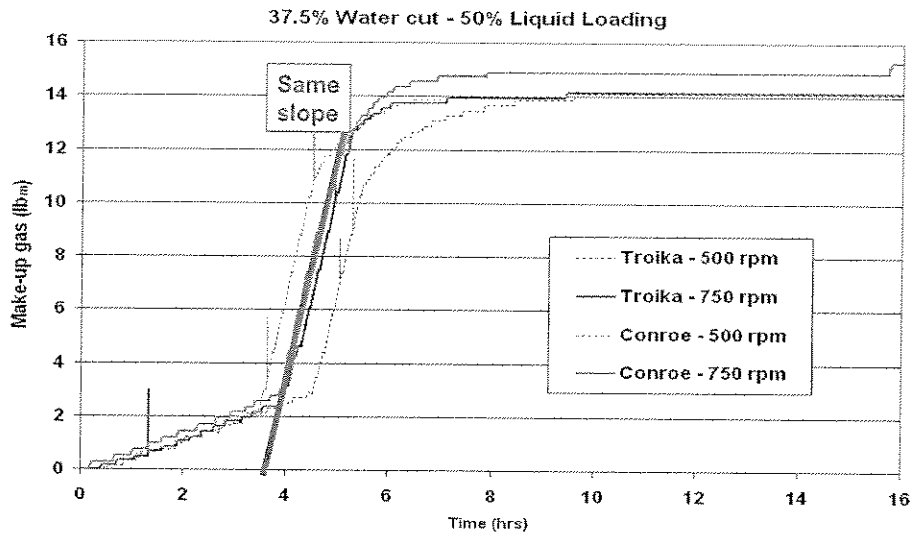
Troika Experiments



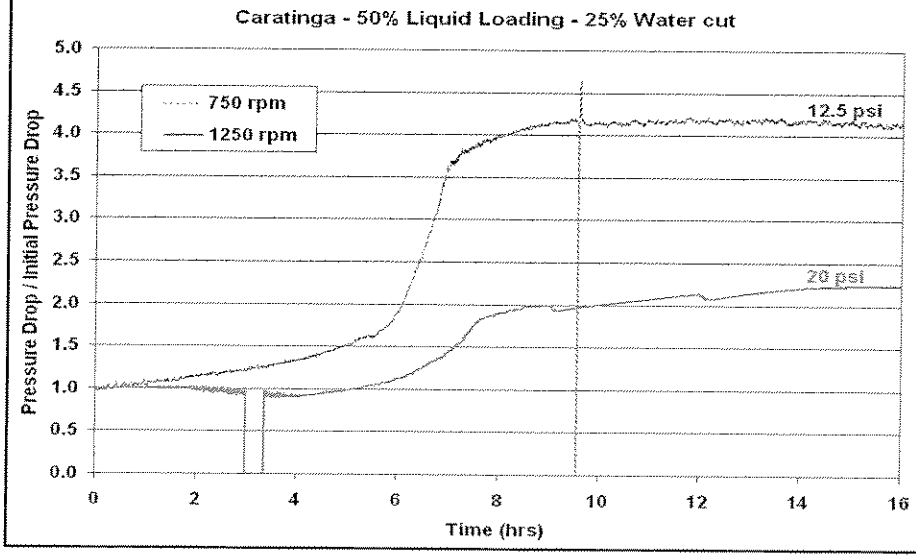
Troika Experiments



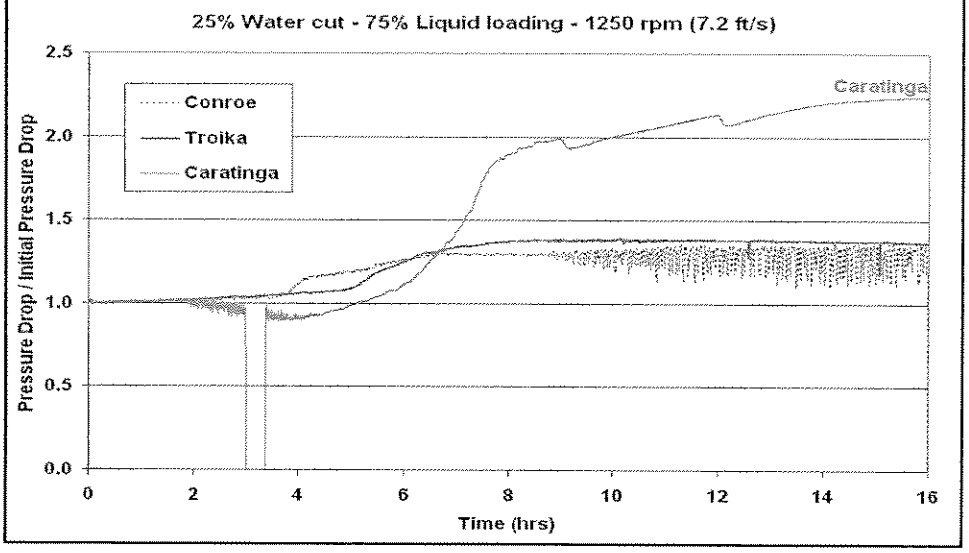
Make-up Gas Limitations



Caratinga Experiments



Fluid Comparisons



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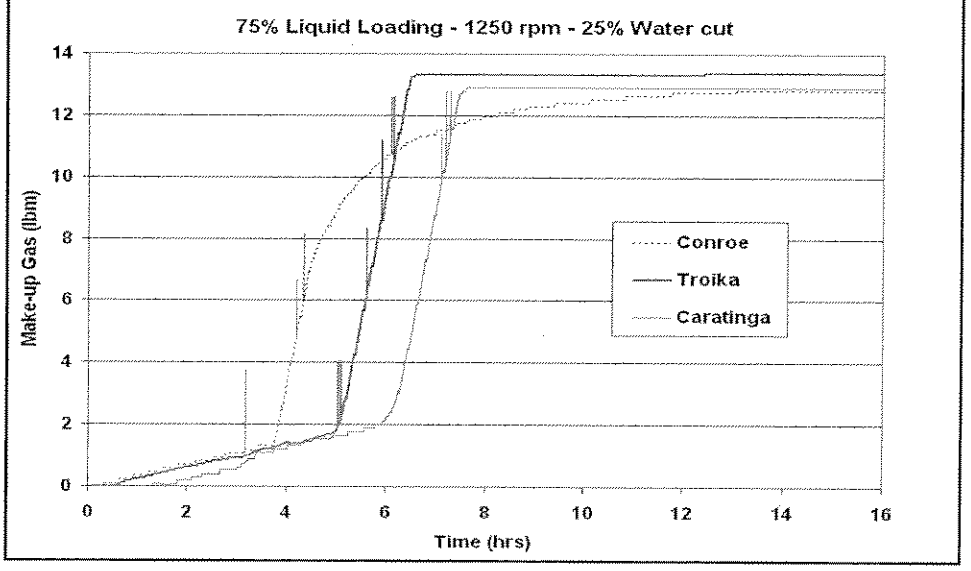
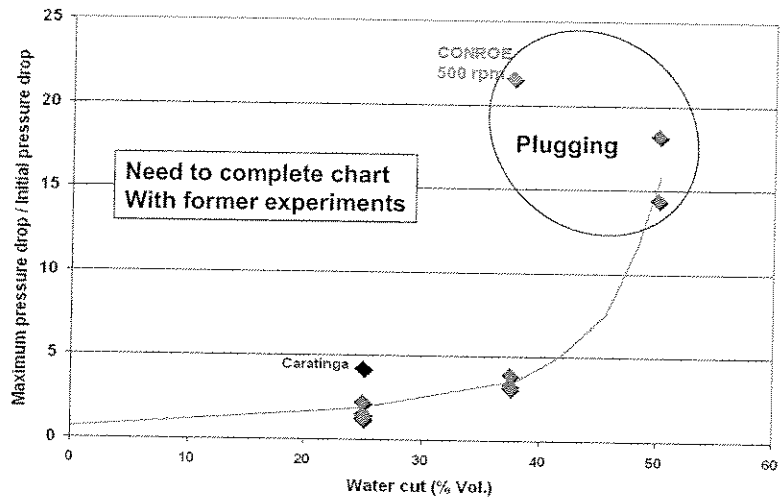


Pressure Drop Increase



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Conroe Conclusions

- Strong velocity effect between 2.2 ft/s and 3.9 ft/s on plugging behavior
  - No effect seen above 3.9 ft/s
- Little mass transfer limitations for pumping at or above 3.9 ft/s
  - Complete water conversion for three fluids
    - No plugging condition
- Conroe plugs severely at 50% water cut
  - All fluids failed at 50% water cut

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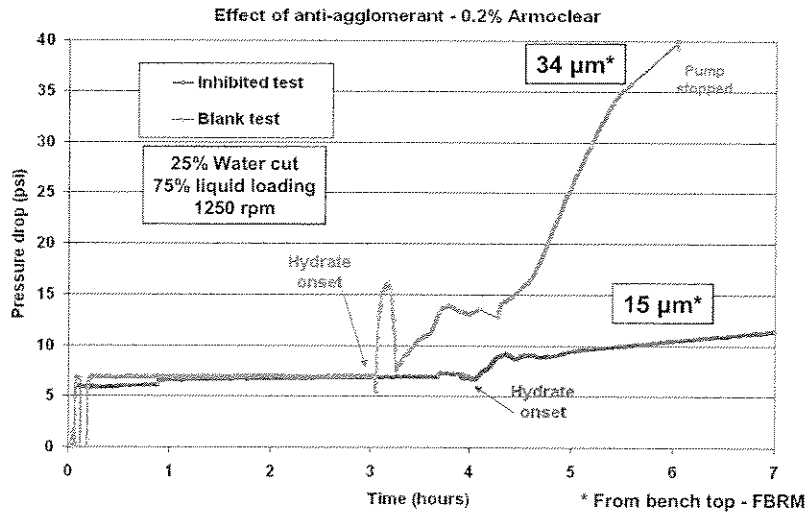
Citgo 19 – Additive Tests

- Additives
  - Dosage for 25% fresh water
    - 1,000 psia – 1.5%
    - 2,000 psia – 2.5%
  - Experiment at 0.2% additive
    - Change droplet size while minimizing anti-agglomerant effect (under-inhibited)
    - 25% Water cut – 75% liquid loading – 1250 rpm

Additive Effect – Citgo 19



* From bench top - FBRM

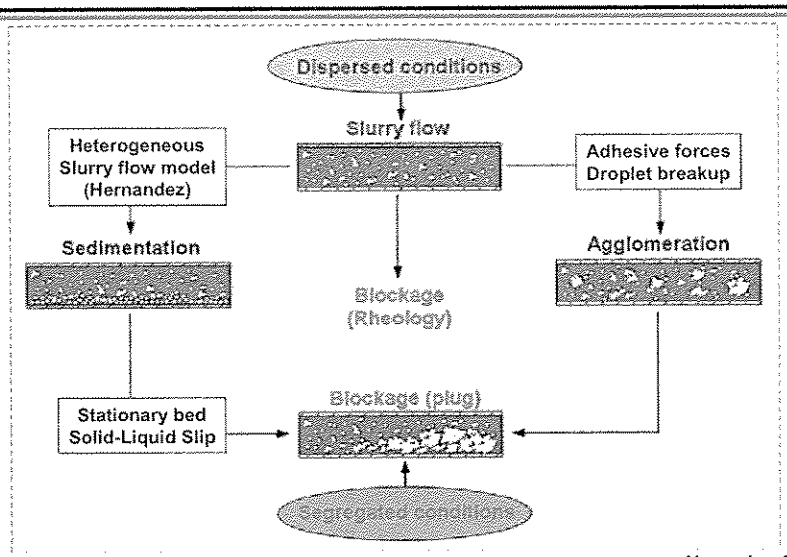
Blake Experiments

- Sample reconditioned in 2006
- Two rocking tests (+/- 5 deg – 120 s)
  - 50% liquid loading, 25% water cut, fresh water
  - Constant volume – Constant pressure
  - 5°F/hr cooling ramp
- Both tests plugged
- Water separates easily
  - Presence of free water in the pipe

Conclusions

- Plugging regime is fluid specific
  - Difficult to identify plugging regime
  - Blockages may occur differently
    - Slurry with / without sedimentation
    - Agglomerations → plugs or partial plugs
  - Vertical geometry is critical
- Trends once plugging regime is known
- Small amount of AA can make a difference on behavior / rheology

Steady-State Plugging Regime



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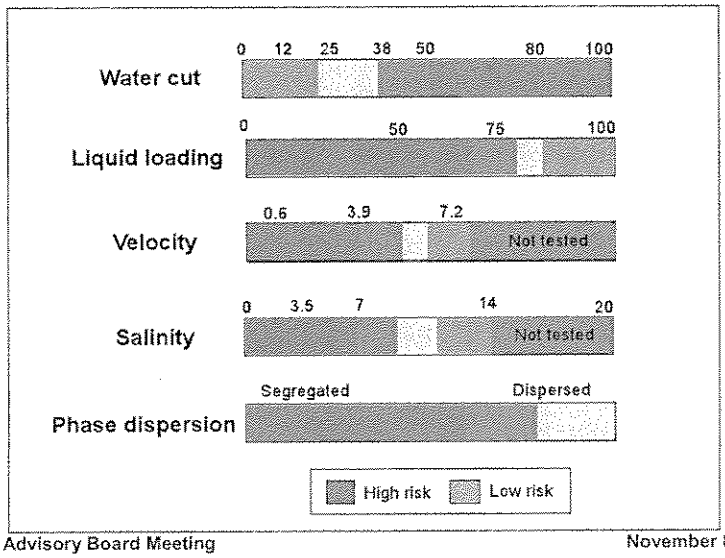
Operating Conditions



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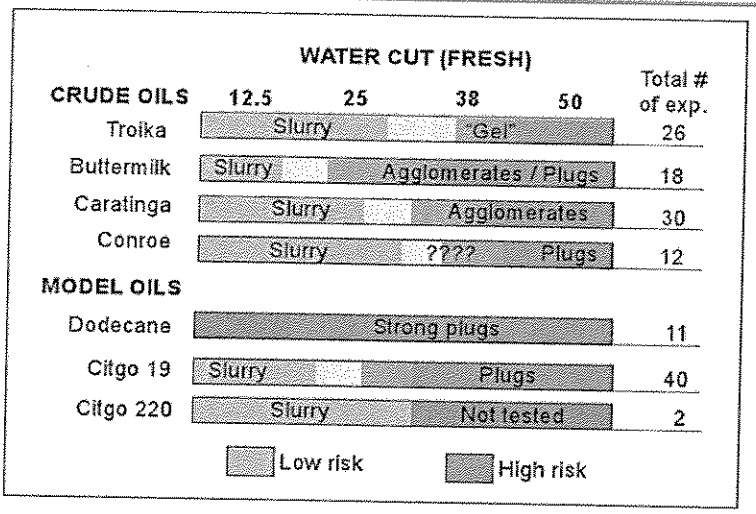
Fluids



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Conclusions

- Facility modifications
  - Make-up gas limitations
  - Identification of plugging regime
    - In-line mass flow meter
    - Ultrasonic measurements

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Future Work

- Continue comparisons with other tests
- Simulate existing experiments
  - Flow loop conditions
- Investigate applicability of slurry flow model to Conroe experiments

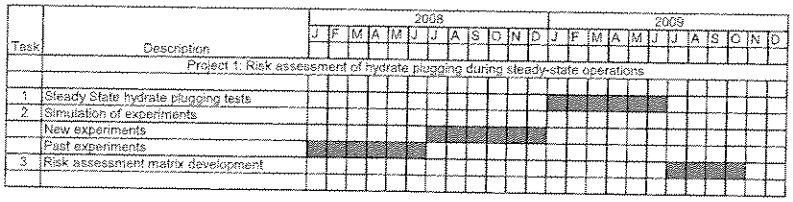
Future Experiments

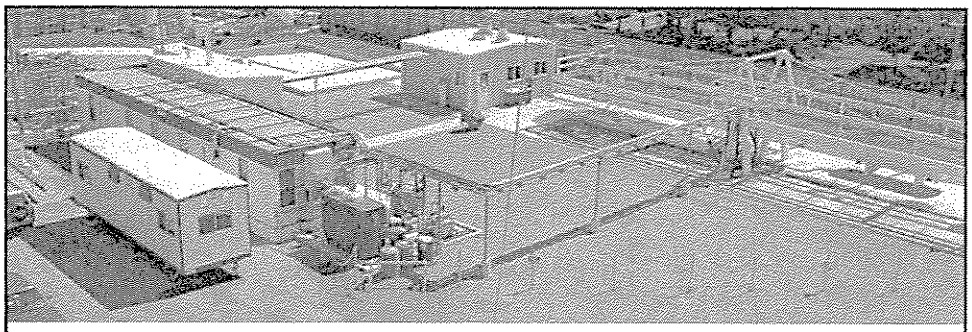
- Primary variables for steady-state
  - Water cut – necessary to find critical water cut
  - Liquid loading > 80%
  - Salinity – may impact plug formation
    - Is plug formation similar when corrected for driving force? Does it change critical water cut?
  - Velocity – limited effect at typical production velocities (4-7 ft/s)
  - Viscosity – Citgo 220 formed a free slurry at 25% water cut – rocking conditions

Future Experiments

- Secondary variables (steady-state)
  - Gas addition
  - Cooling rate
  - Pumping rate (higher than 3.9 ft/s)
  - Liquid loading (between 50 and 75%)
- Focus towards
  - High viscosity, inclination angles, high liquid loading, high water cut & salinity

Steady-State Test Matrix





Steady State Simulations

Ramon S. Domingues

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Outline

- Objectives
- Scope of Programming
  - Simulation scope (constant P, constant V)
  - PVTSim Open Structure
- Test Results
  - Constant Pressure and Volume Tests
  - Experimental Data comparisons
- Future Work

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Objectives

- Develop a simulation tool to predict / understand experimental data
  - Simulate hydrate formation under ideal conditions (equilibrium).
  - Understand effect of operating parameters:
    - Liquid loading, Water cut, Salinity, P, T
- Better design and interpretation of experiments

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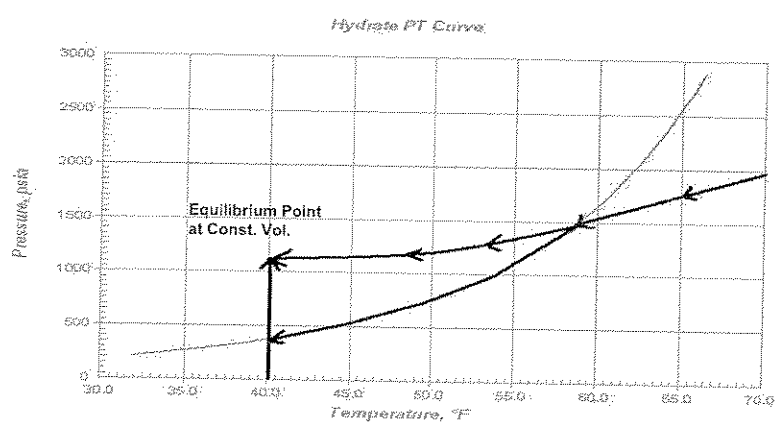
Scope of Programming

- Phase equilibrium curve - Constant Volume



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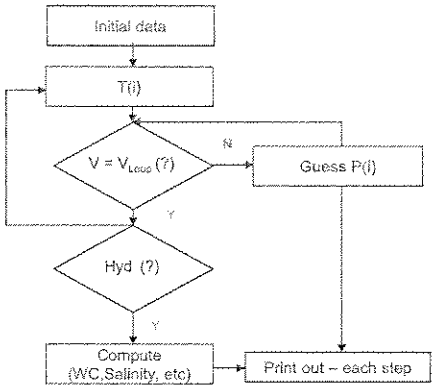
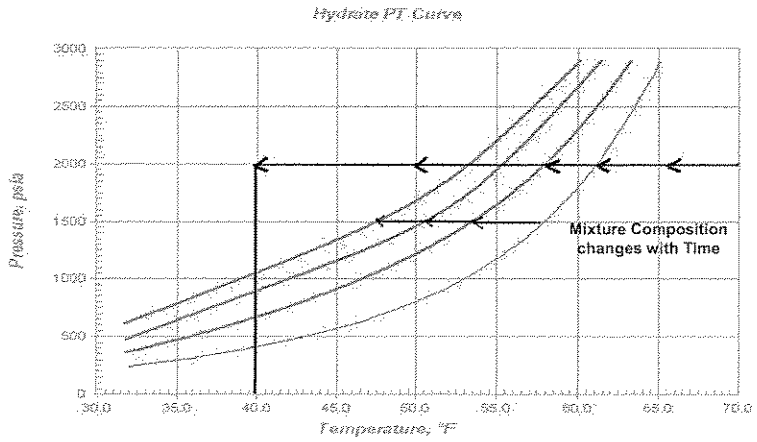
Scope of Programming

- Block diagram - Constant Volume Test



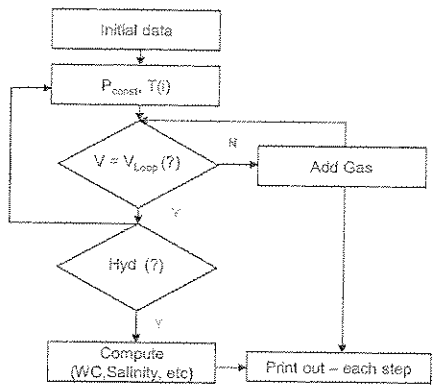
Scope of Programming

- Phase equilibrium curve – Constant Pressure



Scope of Programming

- Block diagram - Constant Pressure Test:

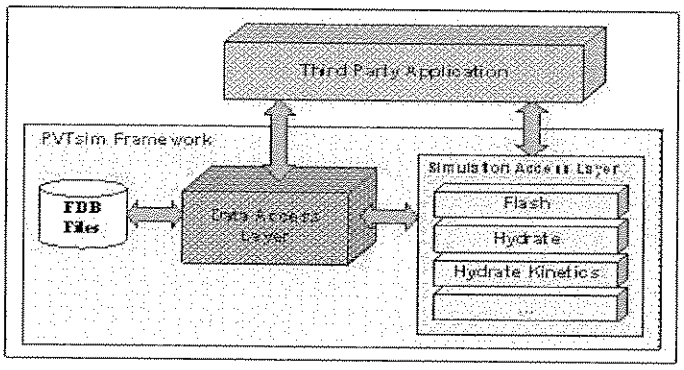


Scope of Programming

- Inputs
  - Initial charge (composition in mole %)
  - Temperature profile (cooling rate)
  - Initial pressure
  - Loop volume
- Outputs
  - Pressure profile (const. volume test)
  - Gas addition (const. pressure test)
  - Water conversion
  - Salinity change
  - Hydrates formed (sI /sII)
  - More outputs added later (GOR, compositions)

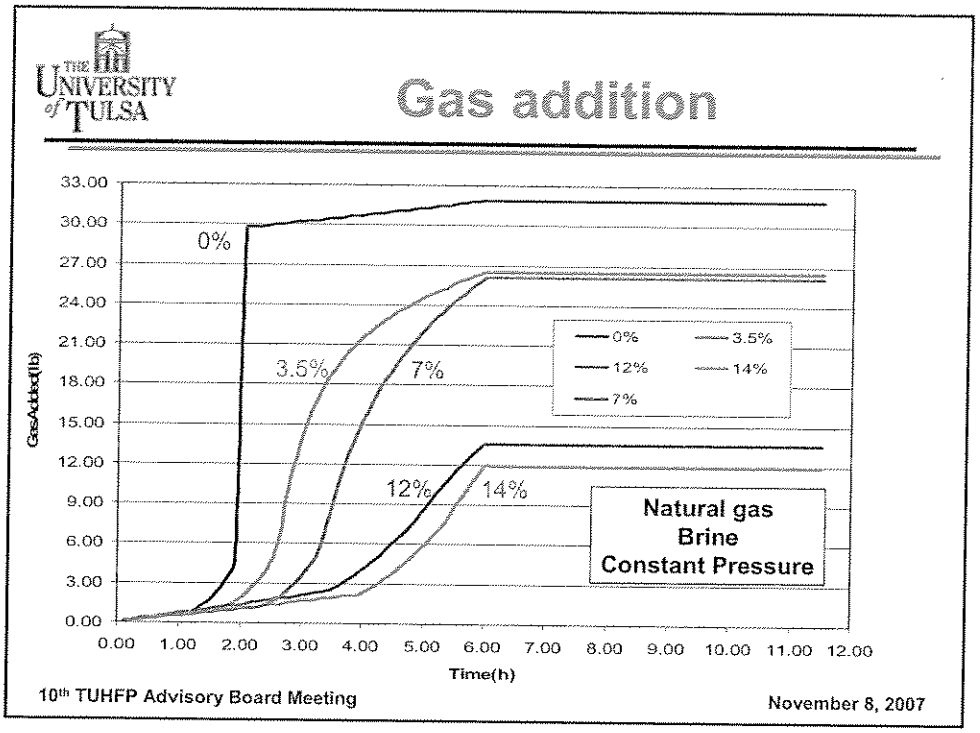
Scope of Programming

- Using PVTSim Hydrates Open structure
  - Macro built in VBA-XL



Simulation Results

- Natural Gas + Brine (different %wt. salinity)
  - 50% liquid loading
  - Salinities (0%, 3.5%, 7%, 12% and 14%)
  - Cooling rate 5°F/hr
  - Constant pressure experiment
    - Gas addition


Gas addition
33.00
30.00
27.00
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
GasAdded(lb)
0%
3.5%
7%
12%
14%
0%
3.5%
12%
14%
7%
Natural gas
Brine
Constant Pressure
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00
Time(h)
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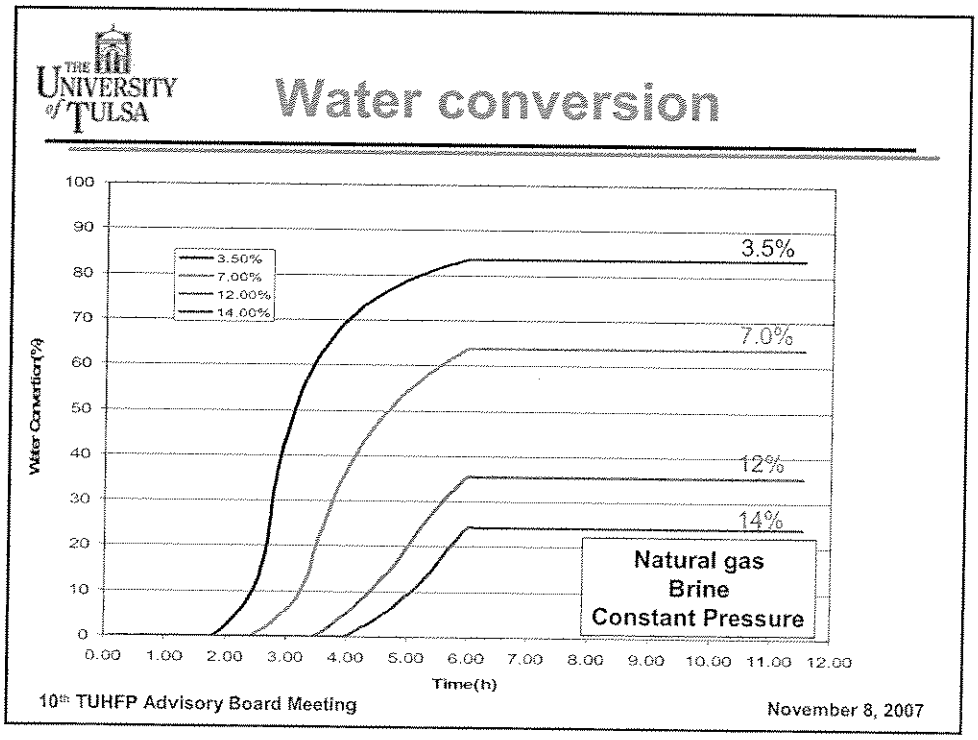
Water conversion
100
90
80
70
60
50
40
30
20
10
0
Water Conversion(%)
3.50%
7.00%
12.00%
14.00%
3.5%
7.0%
12%
14%
Natural gas
Brine
Constant Pressure
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00
Time(h)
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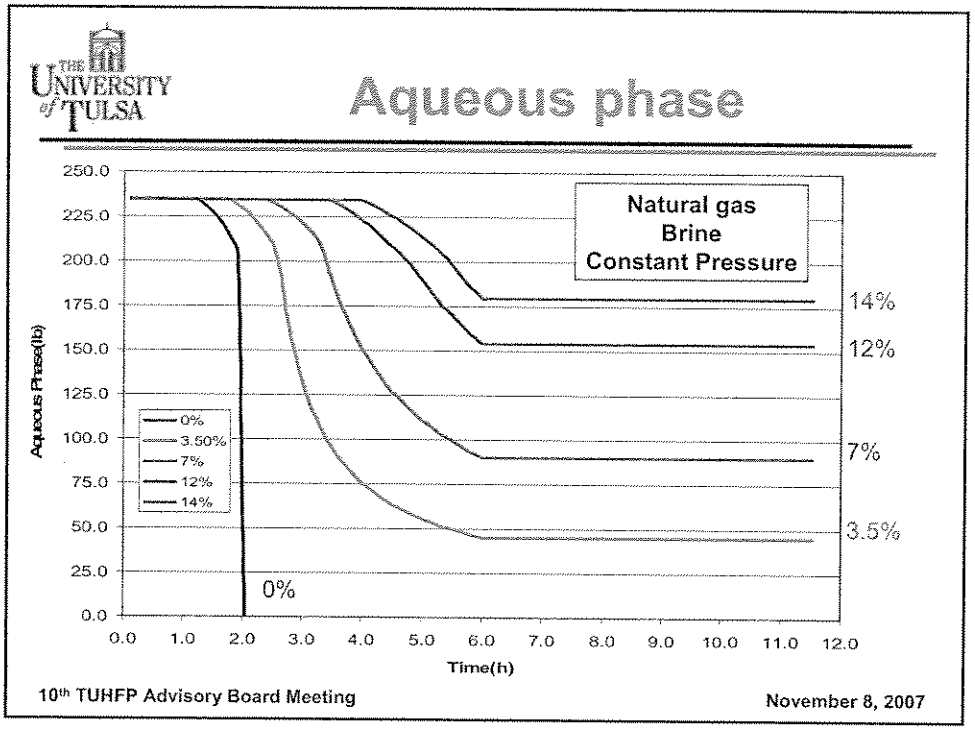
Aqueous phase
Natural gas
Brine
Constant Pressure
Aqueous Phase(lb)
Time(h)
0%
3.50%
7%
12%
14%
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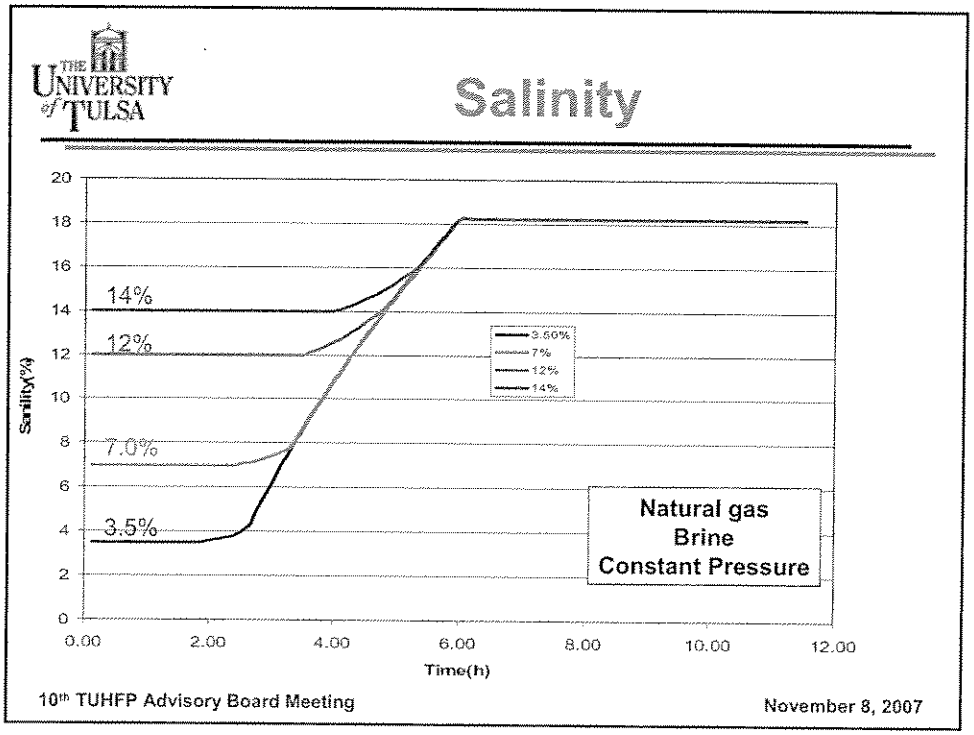
Salinity
Natural gas
Brine
Constant Pressure
Salinity(%)
Time(h)
14%
12%
7.0%
3.5%
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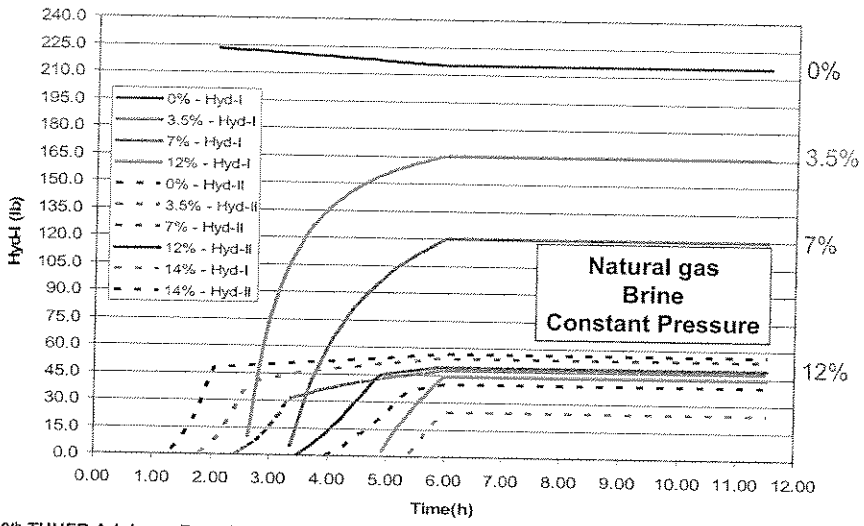
Mass of sI & sII hydrates



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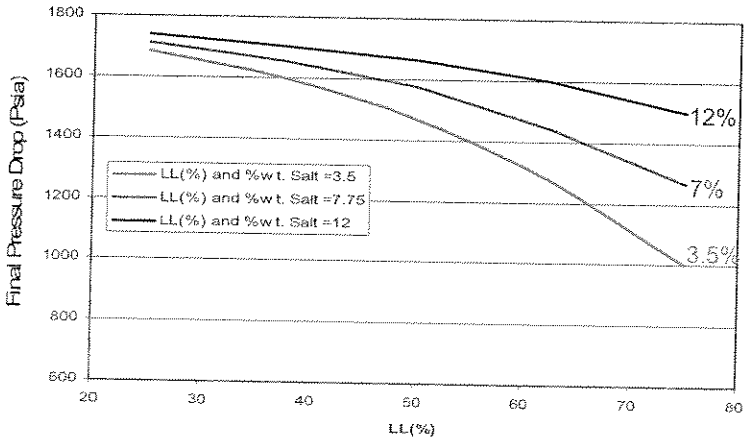
Simulation Results – Const. Vol.

Caratinga: Water cut = 25%



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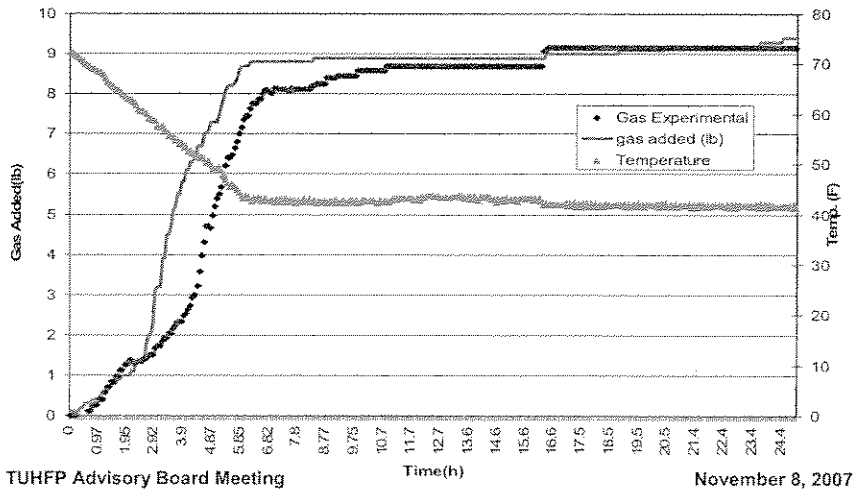
Simulation results

- Shows changes in parameters and composition
  - Salinity increase (thermodynamically inhibited)
  - Change in sI/sII versus time
    - Important in water conversion calculations
- Trends consistent with change in parameters and time
  - Issues with high liquid loading

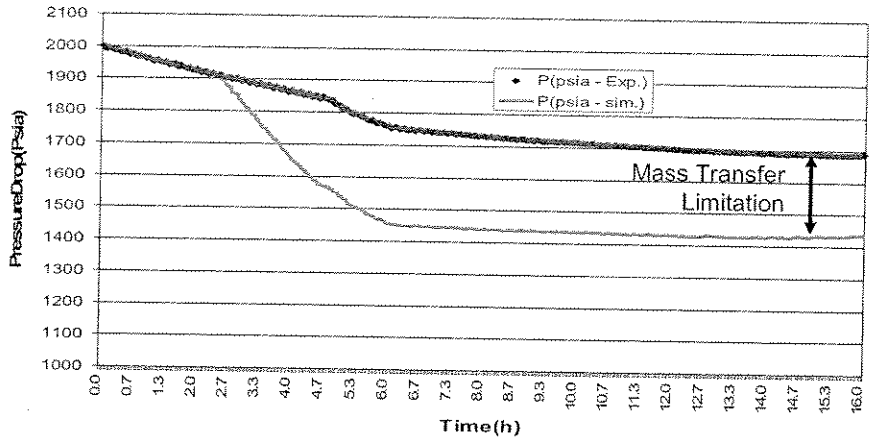
Case Example – Const. P.

ButterMilk: LL=50%, WC=25%, 3.5%wt. (close to equilibrium)



Case Example – Const. Vol.

Troika: LL=50%, WC=37.5%, 3.5%wt. Salt, Rocking



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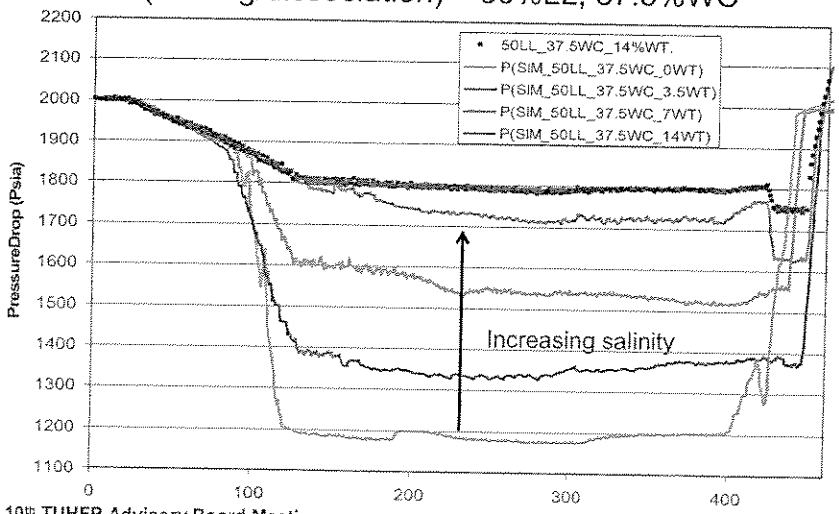
Case Example – Const. Vol.

Troika (rocking/dissociation) – 50%LL, 37.5%WC



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Conclusions

- Flow loop simulation tool is being developed
- Some effects observed
  - Pumping close to equilibrium
  - Hydrate structures change with conditions
  - Constant volume experiments limited to salinities less than 14%
- High liquid loading effect must be understood

Future Work

- Continue tool development
  - Investigate liquid loading effect
  - Develop a non-equilibrium simulator
    - Account for sub-cooling at onset conditions
    - Simulate kinetic rates
- Compare simulation results to test data

Questions

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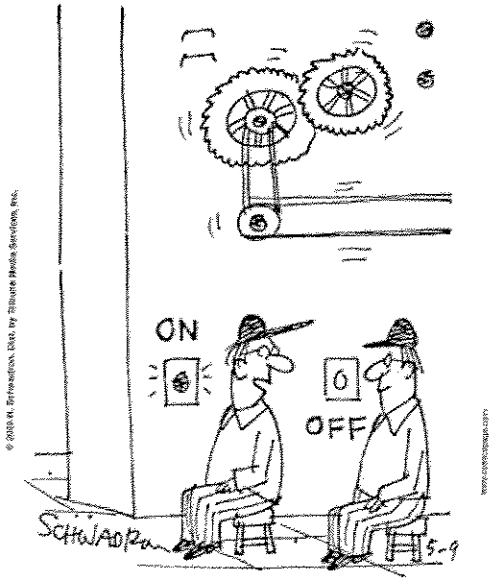
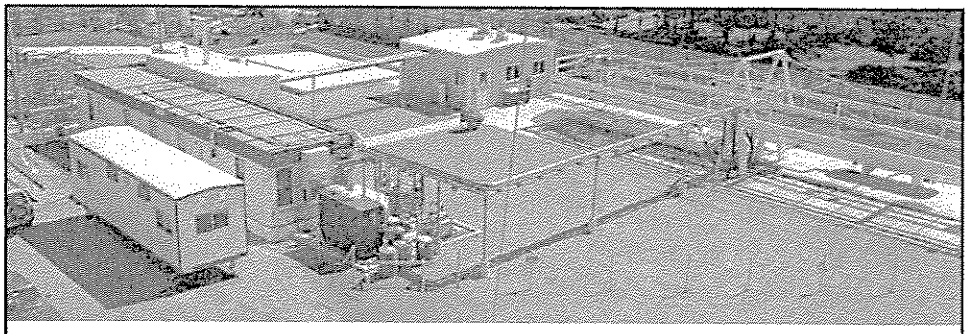
Break – 15 Minutes



"I'm bored! Want to trade places for a while?"



Transient Experiments

Emmanuel Delle-Case

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Transient Experiments

- Estanga (2007) - Results
  - Low spot gas restarts & pumping restarts
  - Plugging risk increases with water segregation, low restart velocities, decreasing salinity
  - Blockages occur very fast (30 min or less)
  - No blockage with non-bridged conditions (water)
  - Inhibitor must be injected prior to shut-in
  - Attempts to compare with OLGA simulations
  - Gas occluded hydrates, "creeping" blockages

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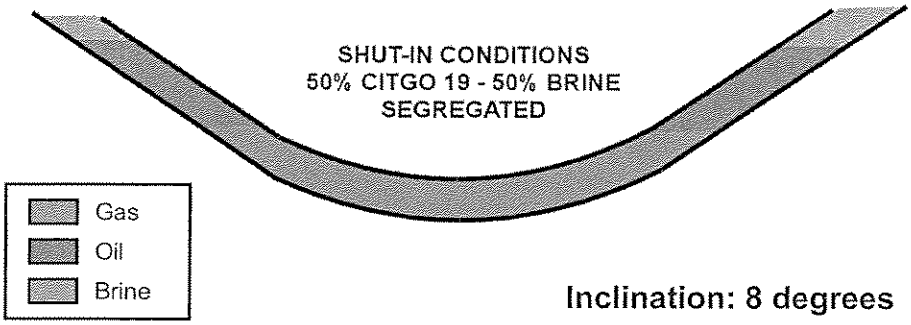
"Creeping" Plugs



Inclination: 8 degrees

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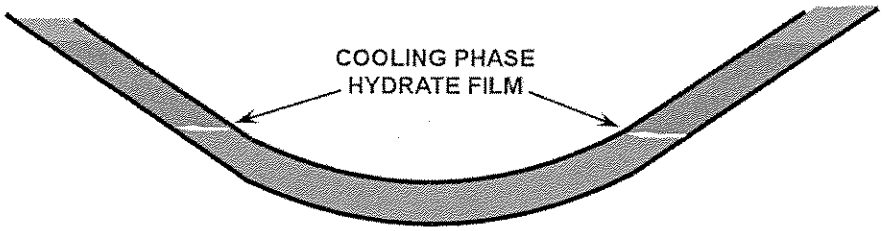
"Creeping" Plugs



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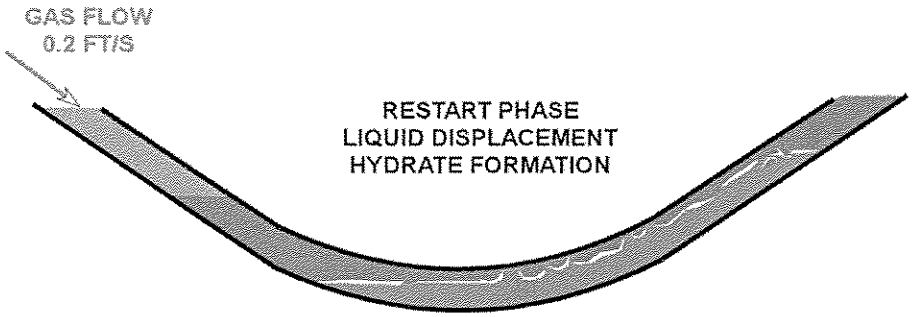
"Creeping" Plugs



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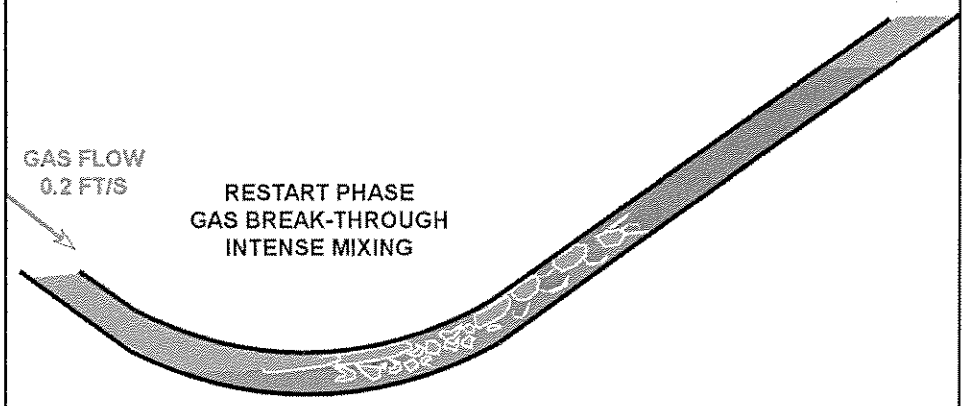
"Creeping" Plugs



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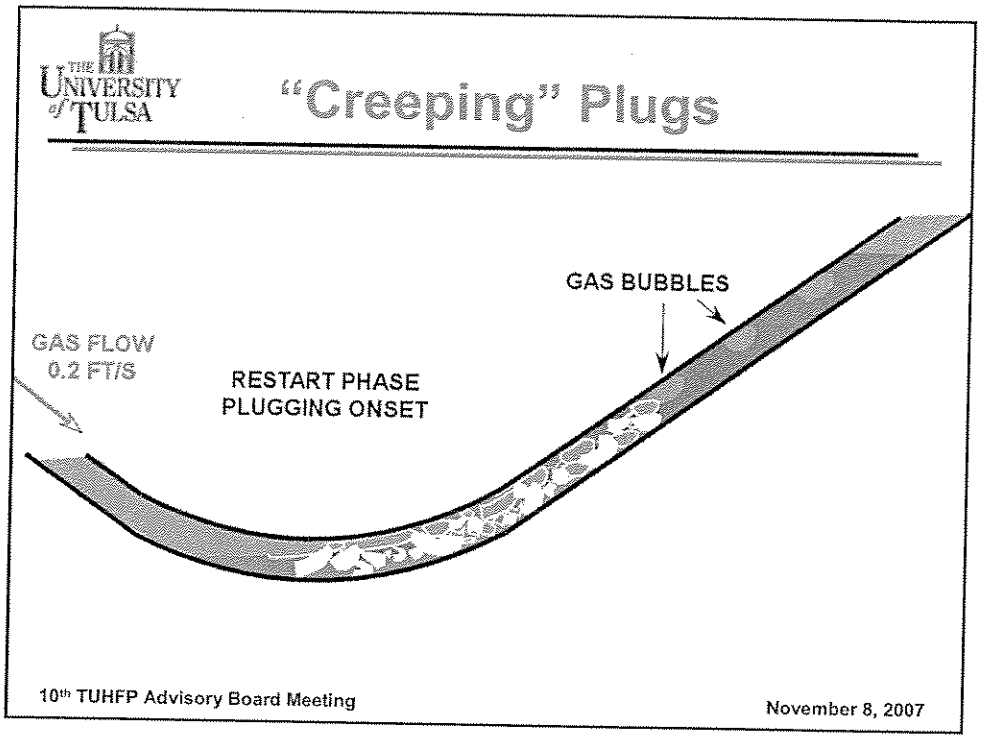
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"Creeping" Plugs
GAS BUBBLES
GAS FLOW
0.2 FT/S
RESTART PHASE
PLUGGING ONSET
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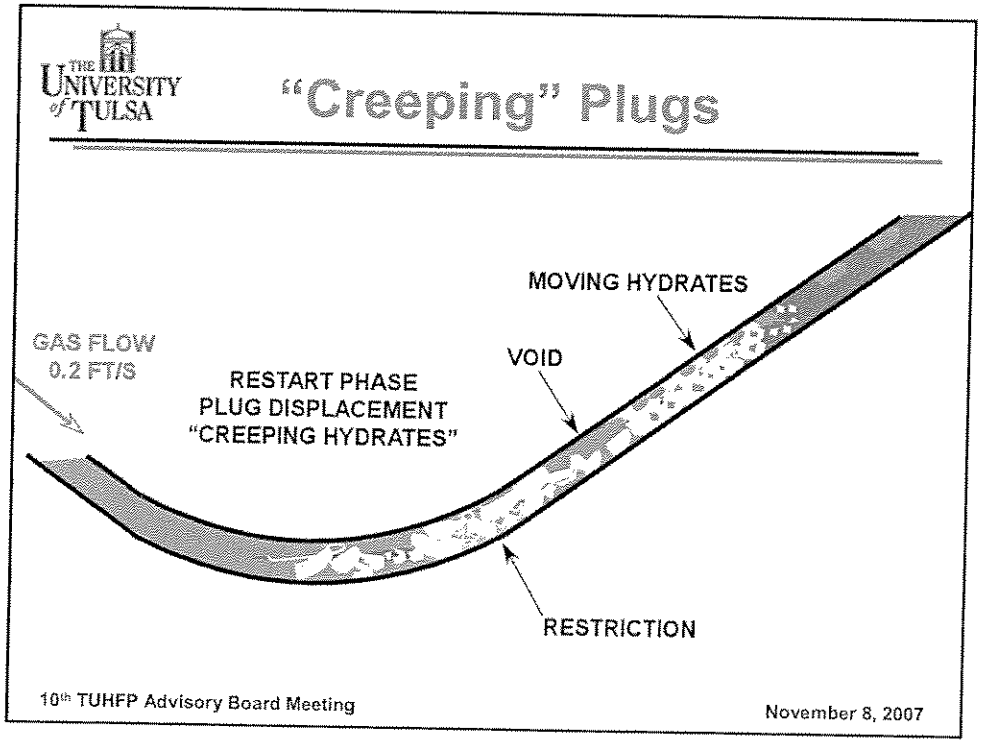
THE UNIVERSITY of TULSA
"Creeping" Plugs
MOVING HYDRATES
GAS FLOW
0.2 FT/S
VOID
RESTART PHASE
PLUG DISPLACEMENT
"CREEPING HYDRATES"
RESTRICTION
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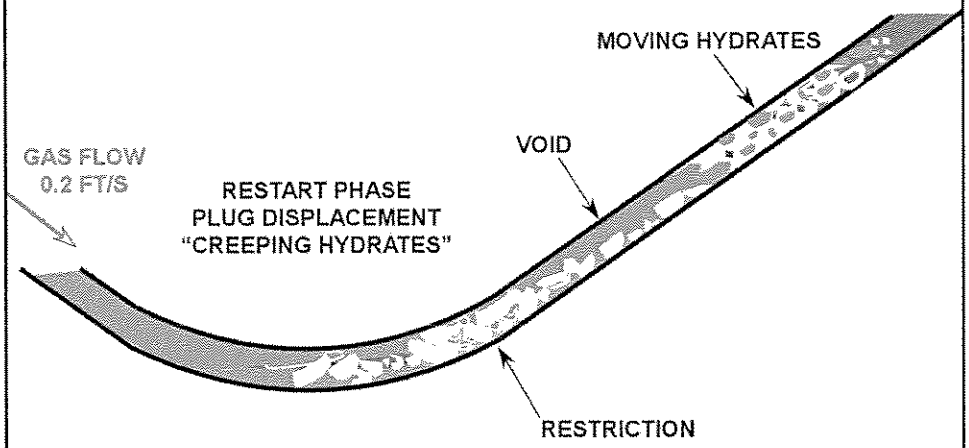
"Creeping" Plugs



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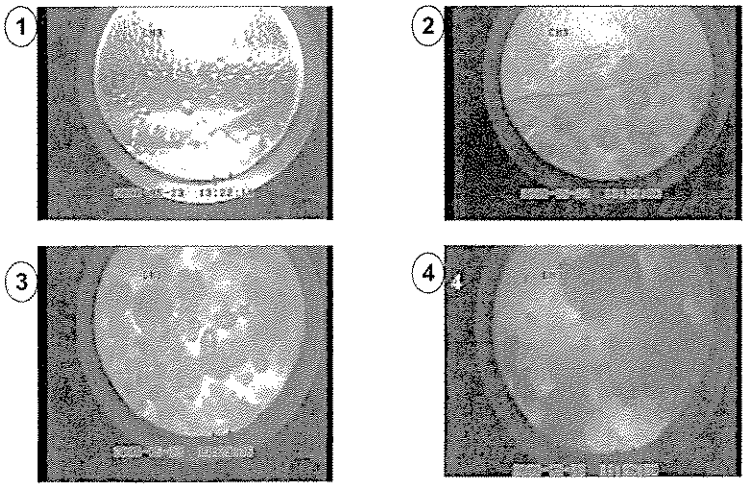
Gas Occluded Hydrates



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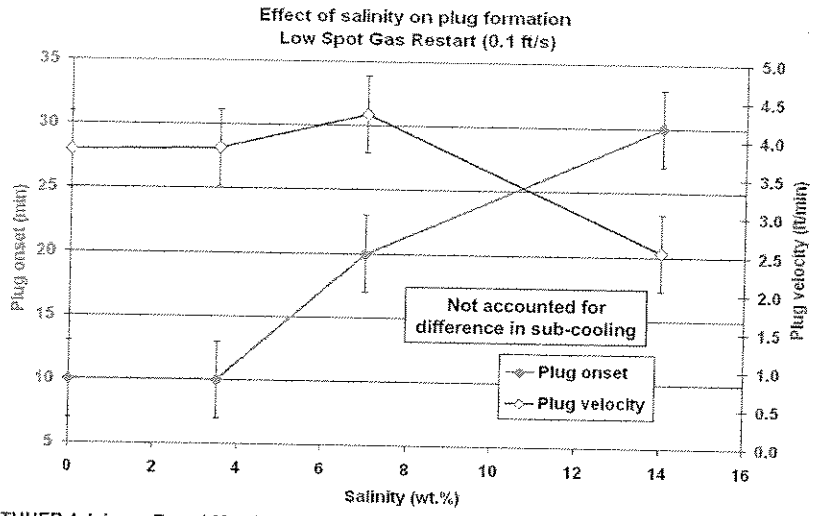
"Creeping" Plugs Velocity



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Risk Assessment

Parameter	Risk Level[¥] Lower	Higher
Phase Distribution	Dispersed	Segregated
Water Holdup	Low < 10%	High ≥ 10%
Mixture Velocity	High (NFI)	Low (NFI)
Diameter	Large (6 in.*)	Small (3 in.*)
Configuration	Horizontal	Low Spot
Salinity	High (14 %)	Low (< 14 %)
Anti-Agglomerant	Effective Dispersion in Water	Poorly/not Dispersed in Water
Low Spot Bridging	Yes	No

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Transient Experiments

- Estanga (2007) - Limitations
  - Very low gas velocity (0.2 ft/s) – leaky valves
  - Only gas restart
  - Control issues – outlet valve "freezing up"
  - No visibility at low spot to visualize fluid displacement / distribution
  - Not a true jumper configuration
    - Need true vertical sections

Future Work

- Understand transient fluid flow in low spots before relating to hydrates
  - Clear, true jumper configuration
- Understand effects of
  - Liquid loading, bridged / non-bridged
  - Restart phase (gas/liquid) and velocity
  - Segregated vs. dispersed conditions
    - How is the water being displaced upon restart?
  - Oil viscosity
- Comparisons with OLGA simulations

Future Work

- Low pressure facility
  - Understand fluid flow aspects
  - Possibly observe cyclopentane hydrates
- Transient studies really need:
  - High pressure systems (hydrate gas)
  - Gas restart vs. liquid restart studies
  - Riser sections
- Riser facility RPSEA project

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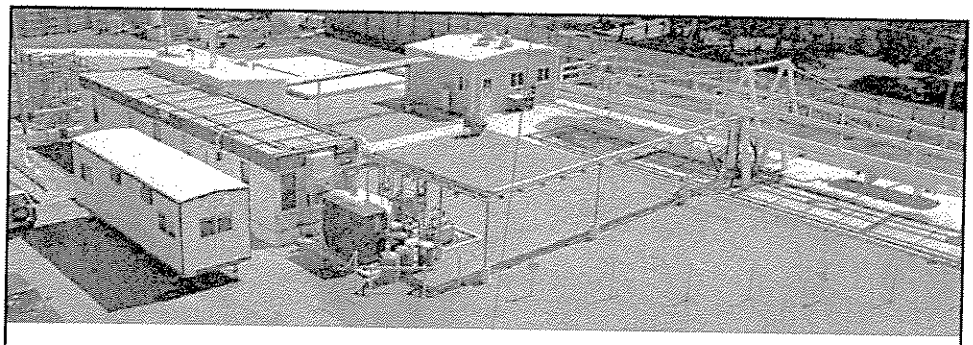

Jumper Study

Angelina Coletta

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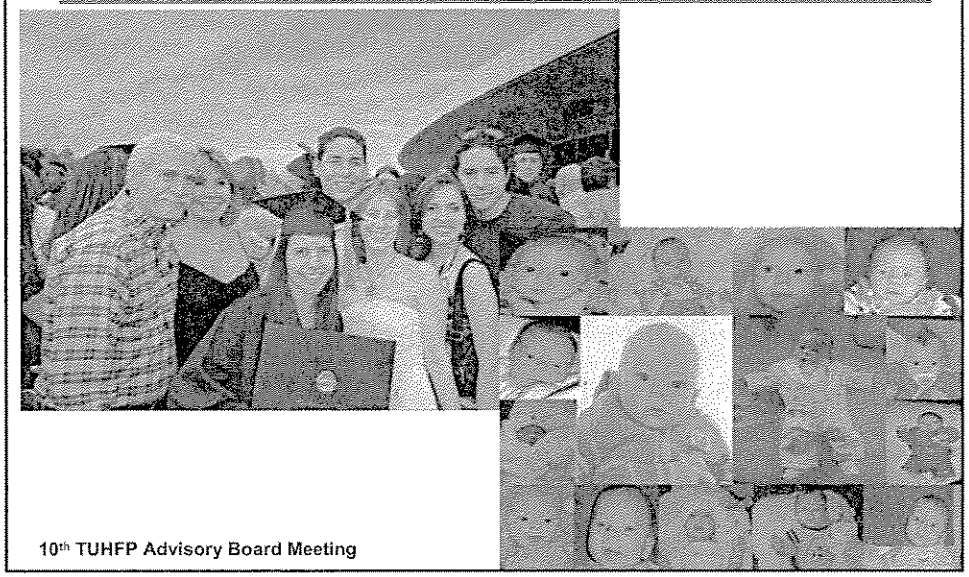
My Family



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Outline

- Objective
- Tasks
- Facility Design
- Test Matrix
- Experimental Program
- Future Work

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Objectives

- Understand water displacement and flow patterns in low spot configuration upon restart
  - Expand to hydrate formation conditions
- Validate existing simulators

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Tasks

- Design and construct jumper facility
  - Run OLGA 5 simulations to aid in the design of the jumper flow loop
- Compare model results with experimental results for different operating conditions
- Quantify impact of hydrates on liquid displacement and their plugging tendencies
  - Cyclopentane

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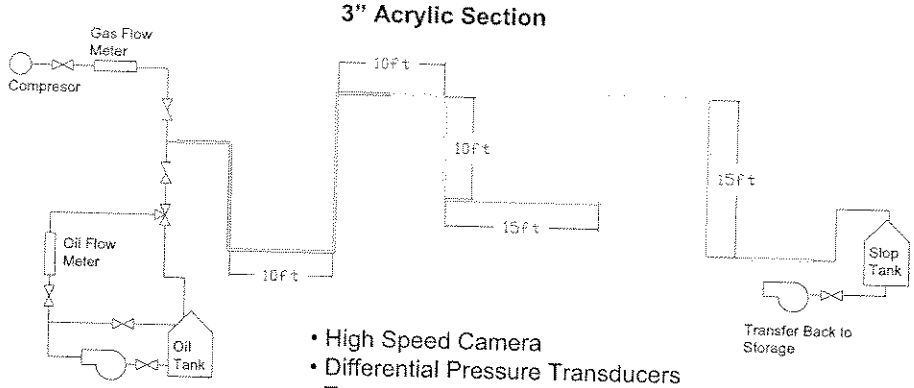
Facility Design

3" Acrylic Section



- High Speed Camera
- Differential Pressure Transducers
- Temperature Transducers
- Conductivity / Capacitance Probes
- Micro-motion Meter

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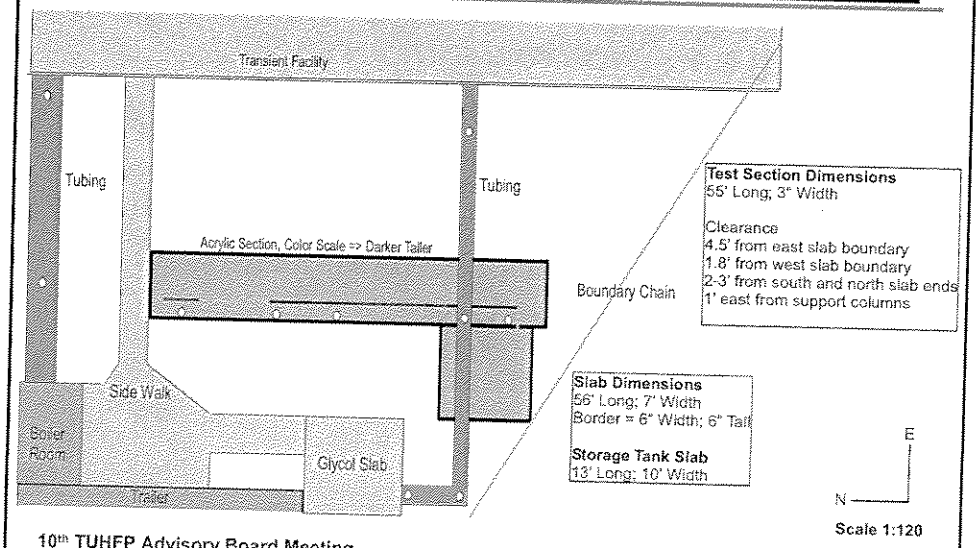
Facility Location



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Test matrix

- About 100 experiments covering
  - Restart phase — Oil/Gas
  - Oil viscosity — 20 cP / 200 cP
  - Rate — 2, 6, 12 ft/s
  - Liquid loading — Partial / Bridging
  - Water cut — 25, 50, 75%

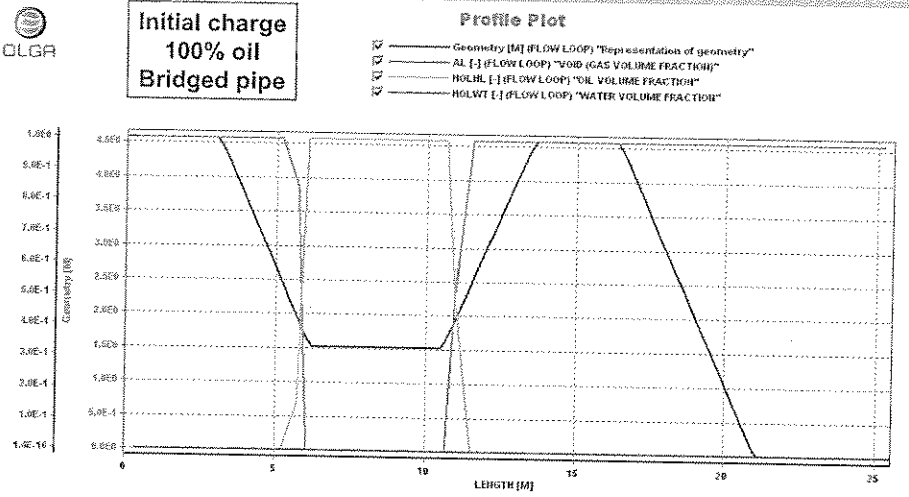
Experimental Program

- Facility design (OLGA simulations)
  - Length of Sections
  - Instrument Locations
  - Slop and Storage Tank Sizes
  - Flow Meter Sizes
  - Compressor Size
- Facility Construction and Shake-down
- Run Tests

Simulation Example

OLGA

Initial charge
100% oil
Bridged pipe



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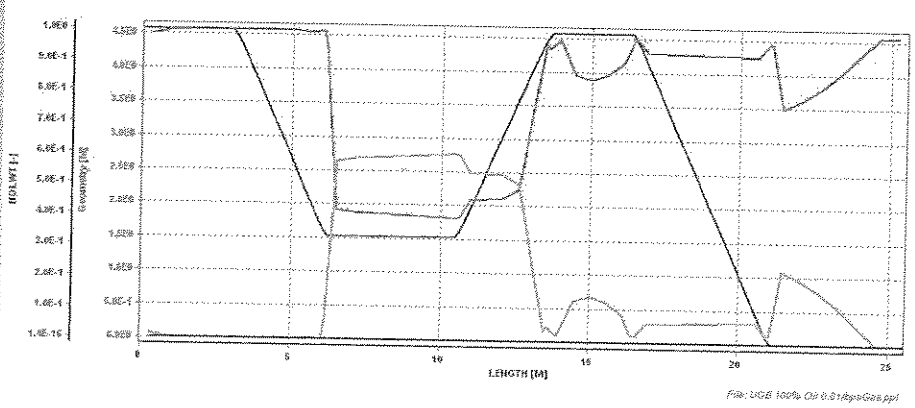
Gas restart (4.1 ft/s)

OLGA

Two minutes
after restart



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Future Work

- Finish simulations with OLGA to finalize the loop design
- Construct and shake-down the facility
- Do experimental tests in new flow loop and compare them to OLGA
  - Locate the water accumulation zones and the flow conditions that favor it

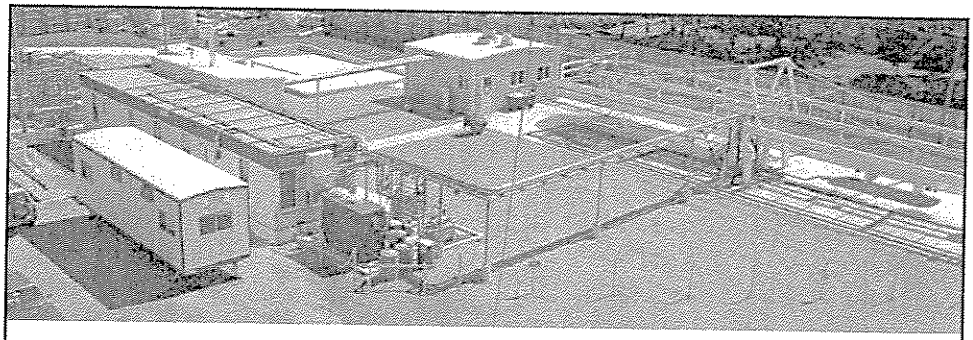
Task Chart

Description	Fall 07		Spring 08				Summer 08				Fall 08				Spring 09				
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Run Simulations																			
Design Flow Loop																			
Build Flow Loop																			
Gas Dominated Restart																			
Liquid Dominated Restart																			
Analysis																			
Write Thesis																			

Hydrate Possible Future Work

- Run experimental test on existing flow loop with cyclopentane
- If cyclopentane forms hydrates in a reasonable time
  - Convert the facility to study hydrate formation and dissociation

Questions



Visualization Studies with High Speed Video Technique

Lissett Barrios

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November 8, 2007

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My Background

- Venezuela
- B.S. in Chemical Engineering
  - Universidad del Zulia (LUZ) - May 1999
- M.S. in Gas Engineering
  - Universidad del Zulia (LUZ) - March 2002
- PhD in Petroleum Engineering
  - The University of Tulsa (TU) – August 2007
- Joined TUHFP in September 2007

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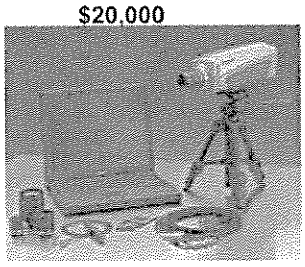
Objectives

- Flow Pattern observation at different operational conditions in FAL
- Droplet size measurements
- Hydrate size measurements
- Visualization studies in jumper facility

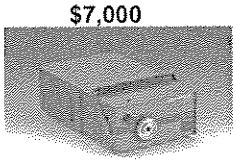
High Speed Video Technique

OLYMPUS i-SPEED

$20,000



$7,000



$300

Frame Rate (fps)	Maxima Resolution (pixel)		Record Time (sec)
	H	V	
60 to 1,000	800	600	4.47
2,000	579	432	4.32
3,000	448	336	4.76
33,000	96	72	9.41

High Speed Video Technique

- Video (Water-Air)- Pumping 750rpm

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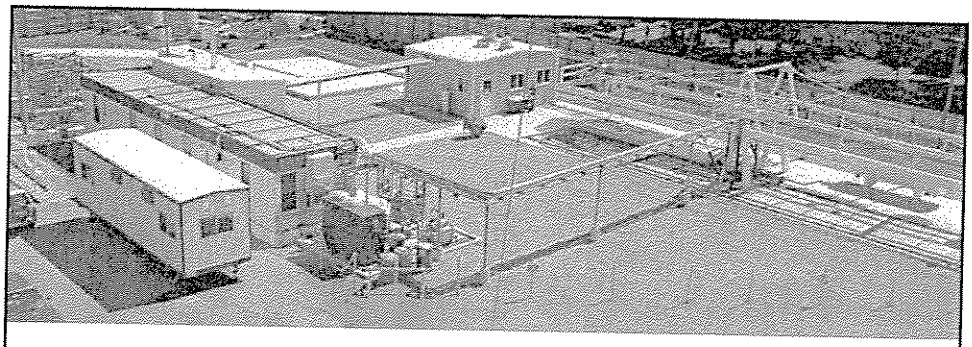

Dispersion Properties w/wo Hydrates

Alisher Yunuskhojayev

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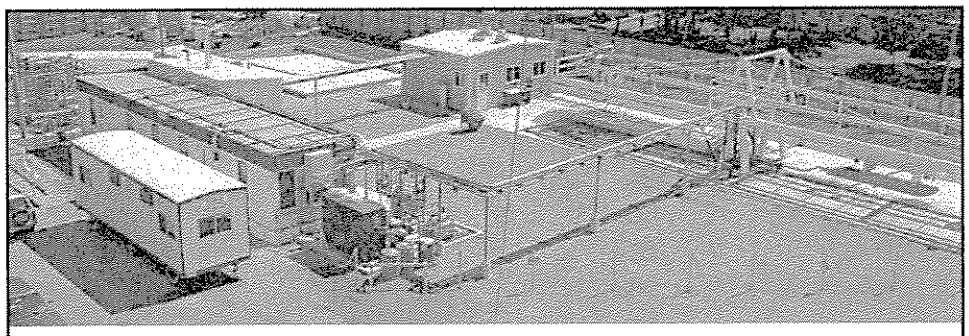
Outline

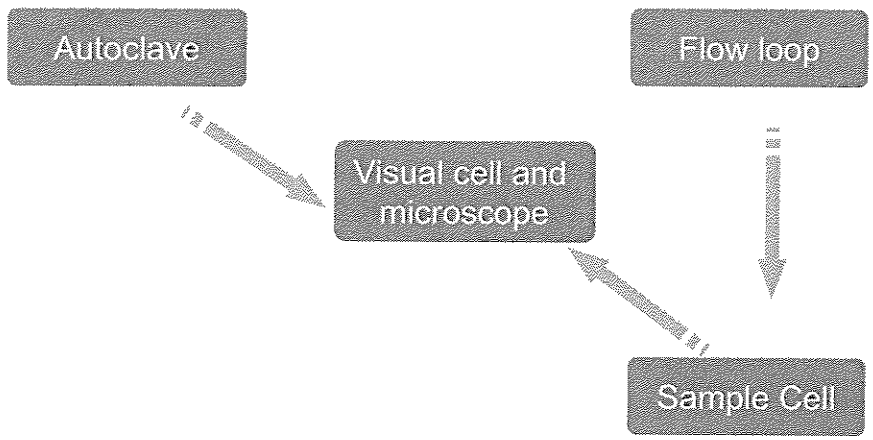
- Summary of Ashutosh Kak's findings
- System Limitations
- Repeatability Analysis
- Current Status
- Future Work



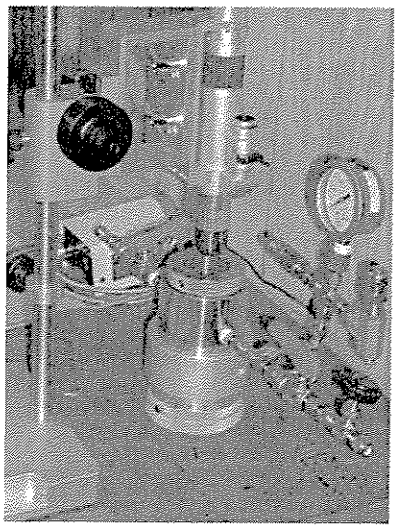
Summary of Findings

High Pressure Setup

Modes of Operation

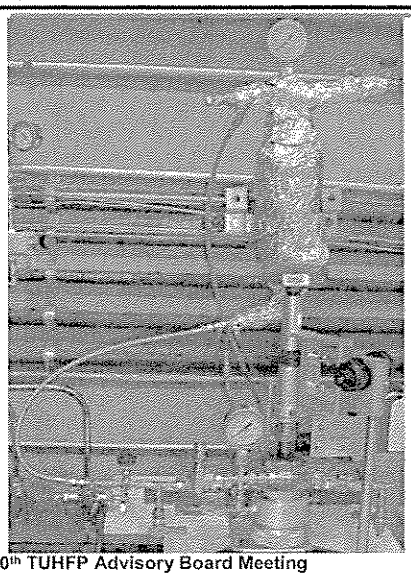


Visual cell



- Made by: Temco
- Design pressure:5000 psi
- Cooling jacket
- Depth 0-3 mm

Sample Cell



- Design pressure:3500 psi
- Volume :500 ml
- Inlet / outlet port size: ¼"
- External cooling coils
- Pressure indicator
- Temperature indicator

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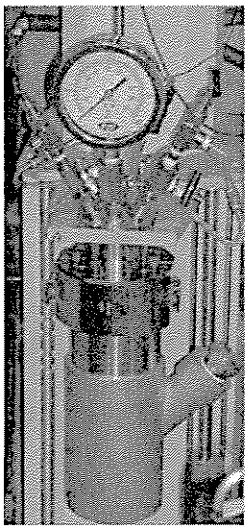
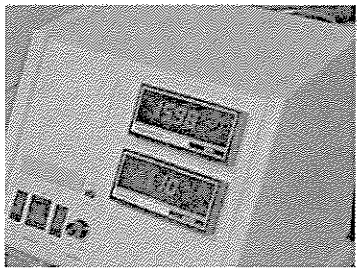
Autoclave



- Made by: Parr
- Design pressure : 5000 psi
- Volume: 1200 ml
- Cooling coils
- Lasentec port at 45° angle
- Motor speed control and display



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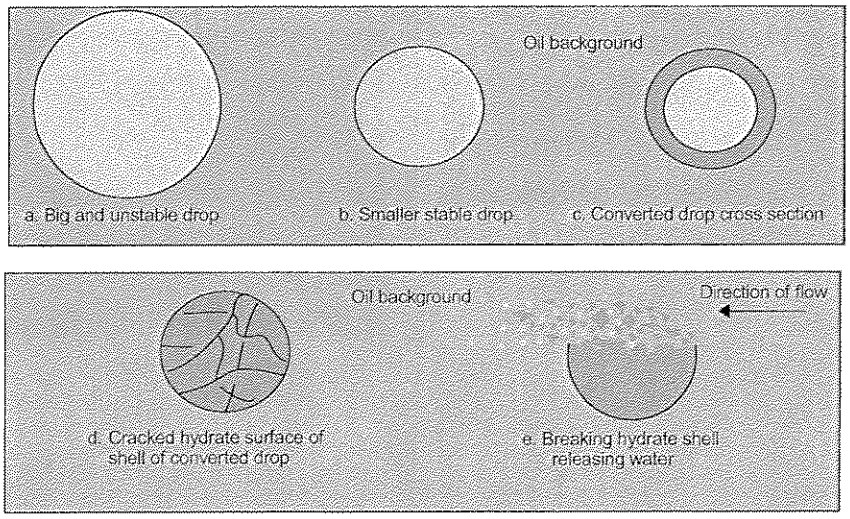
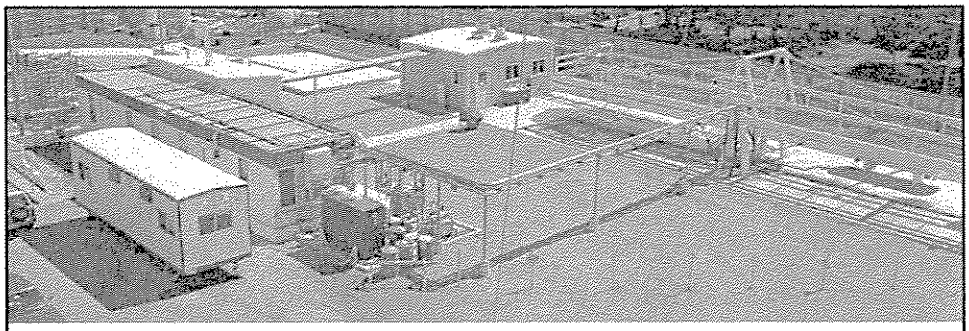
Findings

- Test system validated
  - DSD measured and hydrates observed
- At rest, droplets coated with hydrate film
- Under shear conditions
  - Snow-like
  - Non-spherical particles, flakes
- Droplet break-up believed to be a key mechanism in agglomeration
  - Hypothesis for droplet break-up proposed

Hypothesis for Drop Breakup





System Limitations

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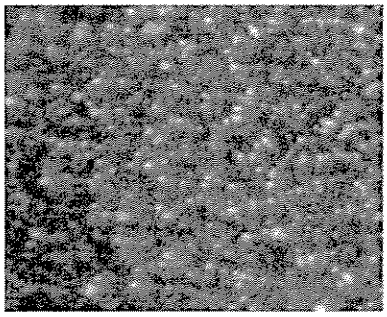
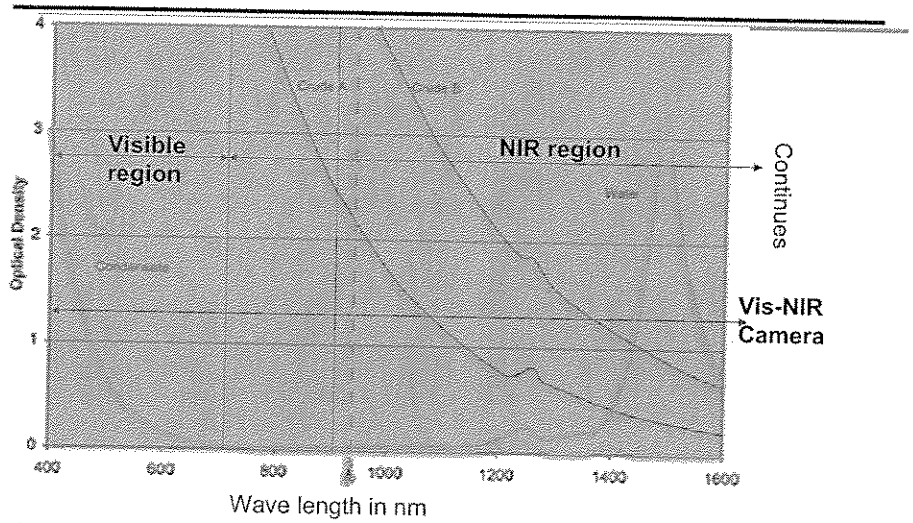
High Water Cuts

- Problems
  - Loss of light
  - Multiple diffractions
  - Overlap of droplets
- Solutions
  - NIR camera?



Troika, 30% Water cut

Optical Spectrum



Optical density is the absorbance of an optical element for a given wavelength λ per unit distance:

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NIR Camera Advantage

Visible range camera NIR Camera

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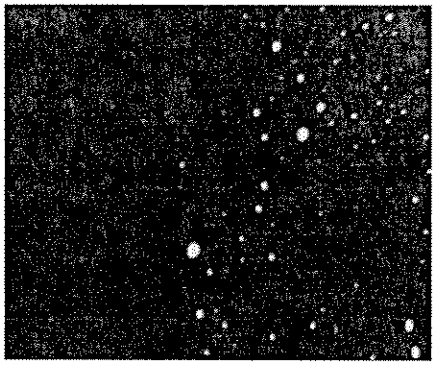
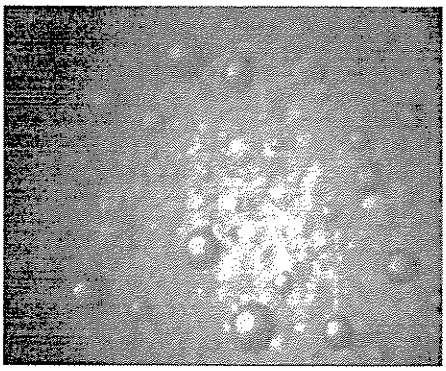
NIR Camera Advantage



Oil: CARATINGA
WC: 20 %
Depth : 0.2 mm
Magnification:1AX
Camera: Visible



Oil : Crude Oil 1
WC: 35 %
Depth: 0.15 mm
Magnification: 3AX
Camera: NIR

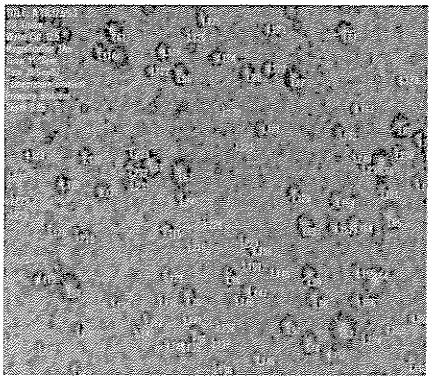
Flow Loop Sampling Issues

- Joule-Thomson Effect
  - Valve freeze
  - Needs steam tracing
- Temperature control of sampling cylinder
  - Needs higher coolant flow rate

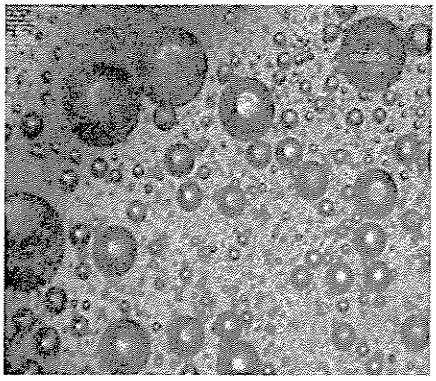
Hydrate visualization

- Droplets are not distinguishable and non-spherical
- Cloudy hydrate slush observed
- Can not observe individual hydrate particles

Pictures (Emulsions)

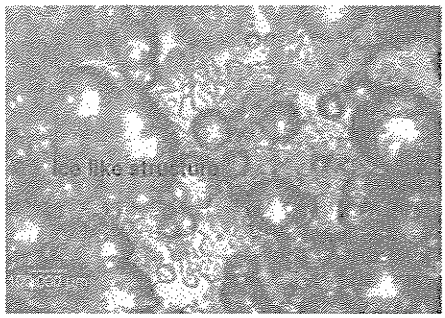


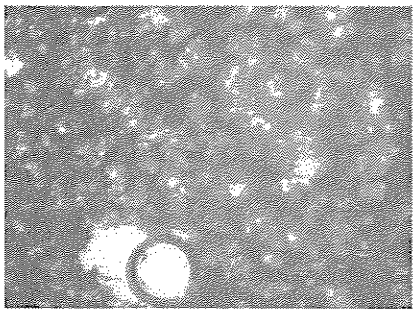
Title: A-TR-1(RS)
Oil: Troika WC: 12.5 %
Temp: 70 F Press: 1500 psi
Mag:1Ax Depth:0.15 mm



Title: A-MO-5(WC)
Oil: Citgo19 WC: 15 %
Temp: 70 F Press: 700psi
Mag:3Ax Depth:0.3mm

Pictures (Hydrates)



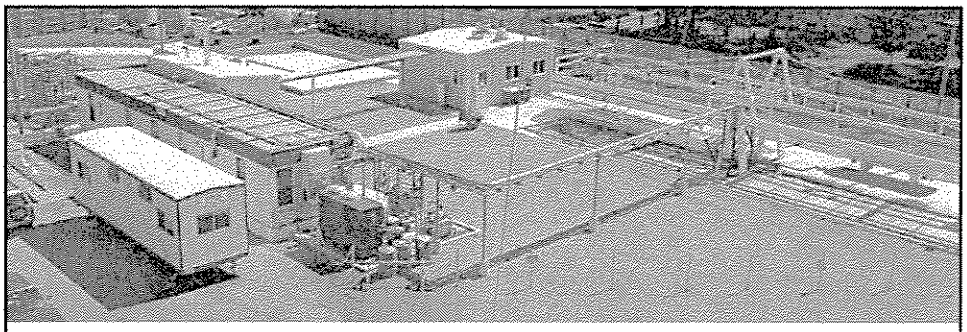


Title: A-13-TR-4

Oil: Troika	Water cut: 12.5 %
Temp: 40 F	Press: 1500 psi
Mag:1Ax	Depth:0.3 mm

Title: A-13-TR-4

Oil: Troika	Water cut: 12.5 %
Temp: 35 F	Press: 1500 psi
Mag:3Ax	Depth:0.3 mm

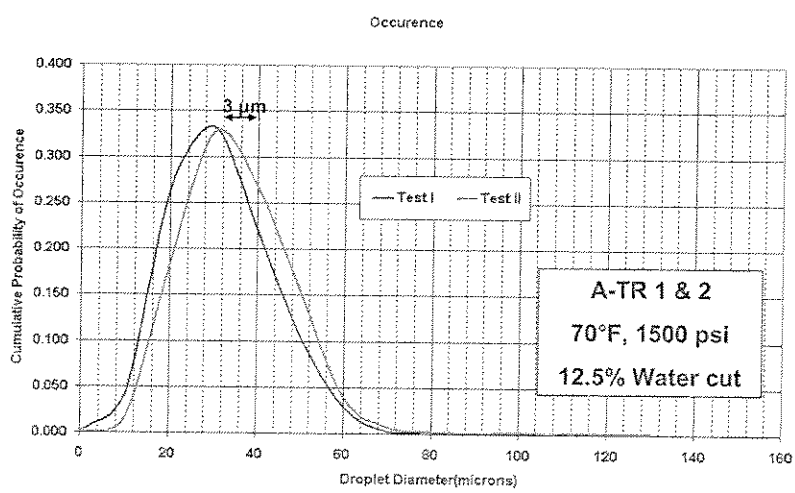


Repeatability Analysis

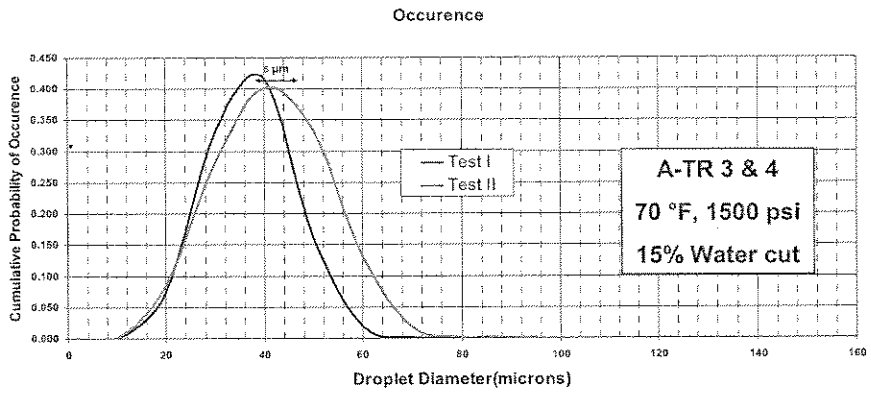
Test Matrix

System	Name	Oil	WC	RPM	Temperature(°F)	Pressure (psi)	Additive % of water	Remarks
A	TR-1	Troika	12.5	1000 rpm	70	1500	0	stable
A	TR-2	Troika	12.5	1000 rpm	70	1500	0	stable
A	TR-3	Troika	15.0	1000 rpm	70	1500	0	stable
A	TR-4	Troika	15.0	1000 rpm	70	1500	0	stable

Repeatibility Analysis



Repeatibility Analysis



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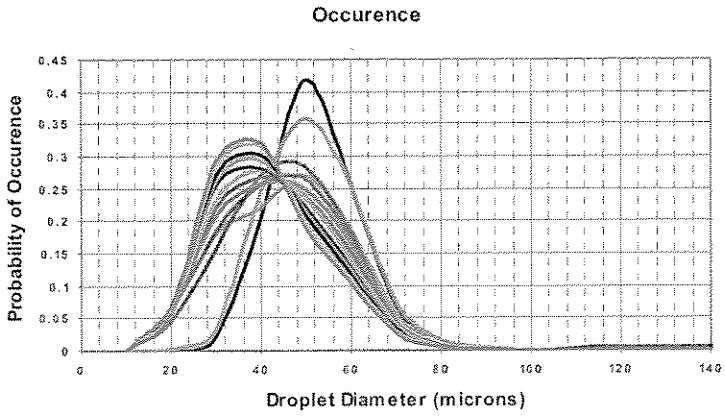
Repeatibility Analysis



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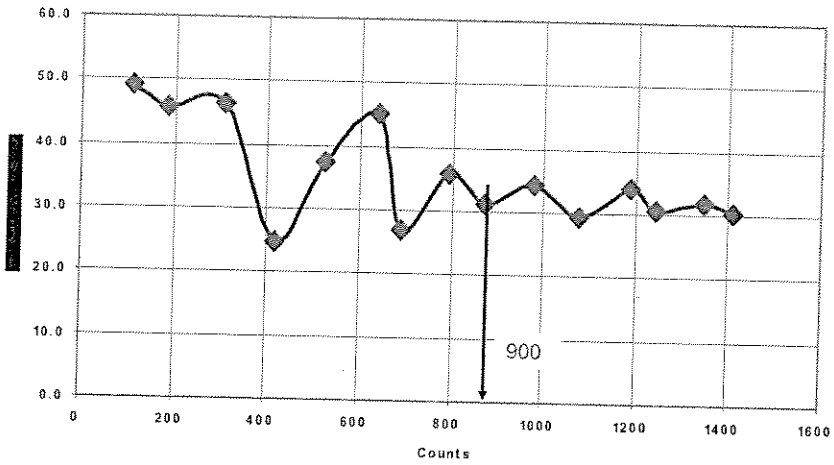
Repeatibility Analysis



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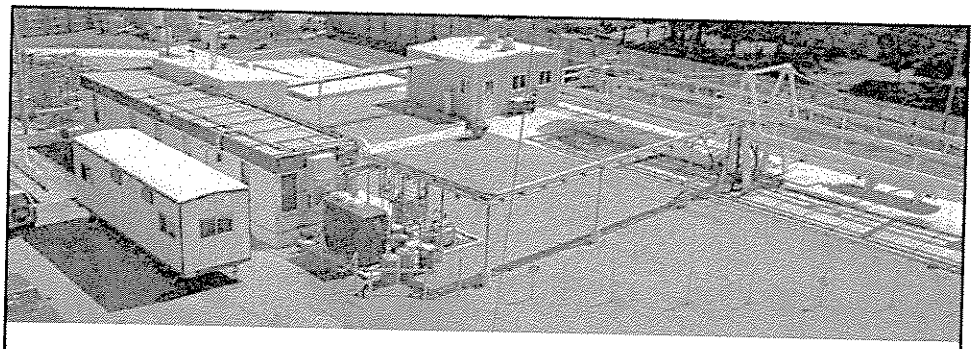

Current Status

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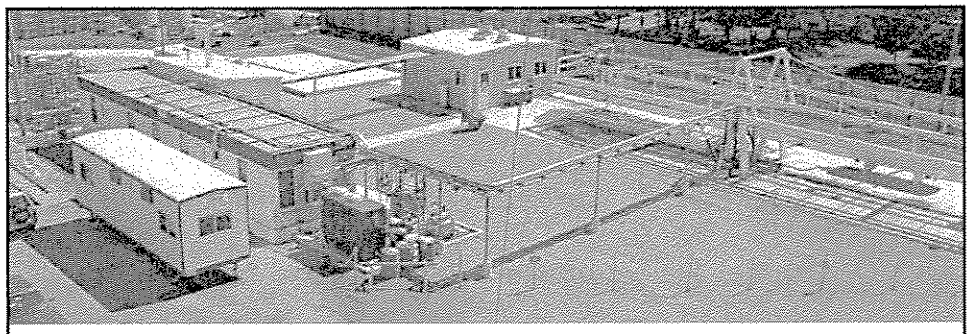
Current Status

- Droplet counting technique refined
  - Criterion for droplet counting established
- Repeatability demonstrated
  - Autoclave sampling validated
  - Macro for DSD improved and expanded
- Flow loop sampling technique needs improvements
  - Temperature control
  - Demonstrate repeatability



Future Work

Future work

- Instrumentation improvements
  - NIR microscopy for gaining insights into dark crude oils
  - Instrumentation improvement (detection of hydrate onset)
  - Monitor viscosity increase from torque measurements

Future studies

- To better understand behavior and properties of dispersions w/wo hydrates
  - Experimental confirmation of droplet breakup hypothesis
  - Effect of pressure (live oil DSD)
  - Effect of salinity, additives
  - Agglomerates structure at low water cuts
- Possibly relate to plugging characteristics
  - High pressure conditions

Questions

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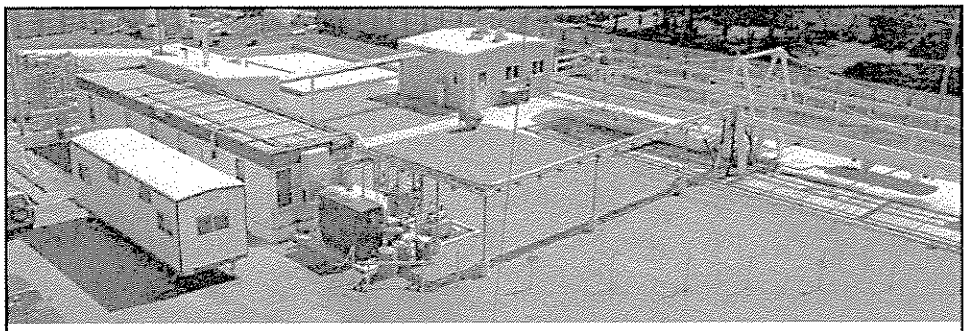

Water Droplet Size & Their Effect on Plugging Tendencies

Rene Sanchez Torres

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Outline

- Objective
- Approach
  - Large and small water droplet size scenario
- Bench top experimental results
  - Water cut, fluid properties, anti-agglomerant, salinity, and shear rate experiments and their effects on water droplet size
  - Droplet size model comparisons

Outline

- Flow loop experimental results
  - Hydrate plugging classification
  - Water droplet size and hydrate plugging tendencies
  - Hydrate plugging risk indicator (HPRI)
- Conclusions
- Future work

Objective

- Establish the effect of water droplet size and dispersion properties on hydrate plugging tendency in flow loop

Approach

1. Characterize water-in-oil emulsions at ambient conditions
   - Water droplet size, viscosity, interfacial tension, density and inversion points
2. Study the effect of the following variables on water droplet size
   - Water cut
   - Fluid properties
   - Hydrate inhibitor and salt concentrations
   - Shear rate / stirring velocity

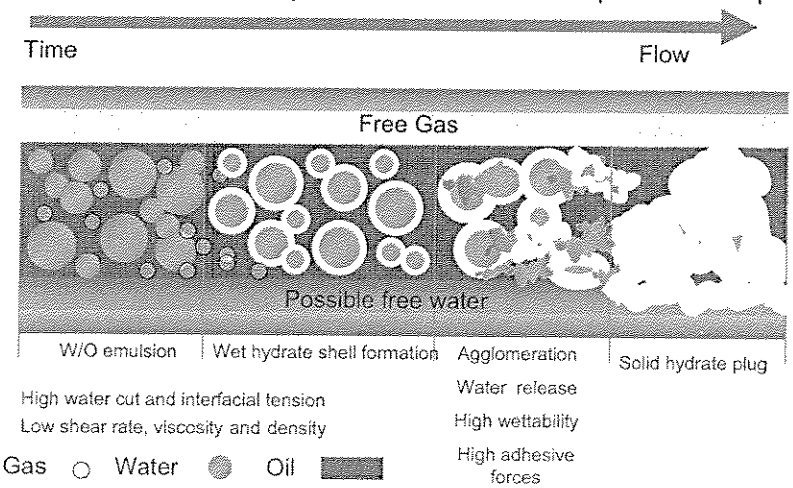
Approach

3. Compare experimental mean and max. droplet size with existing models

4. Establish whether droplet sizes and/or dispersion properties are related to hydrate plugging tendencies

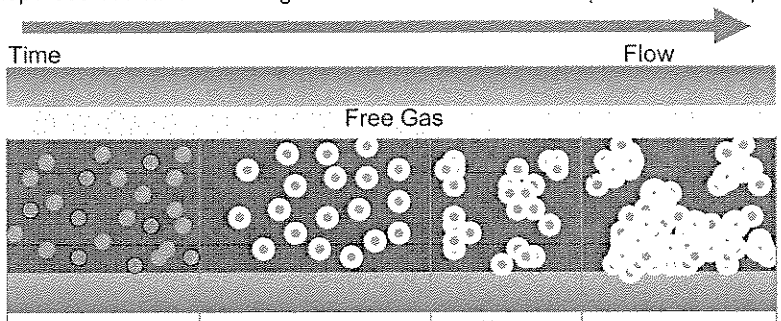
Large Water Droplet Size Scenario

Dispersed scenario - Cooling Phase 70 - 40 °F constant pressure 2000 psi



Small Water Droplet Size Scenario

Dispersed scenario - Cooling Phase 70 - 40 °F constant pressure 2000 psi



W/O Emulsion	Dry hydrate shell formation	Weak agglomeration	Weak hydrate plug
Low water cut and Interfacial tension High shear rate, viscosity, and density		Low water release Low wettability Low adhesive forces	

Gas ○ Water ● Oil ▬

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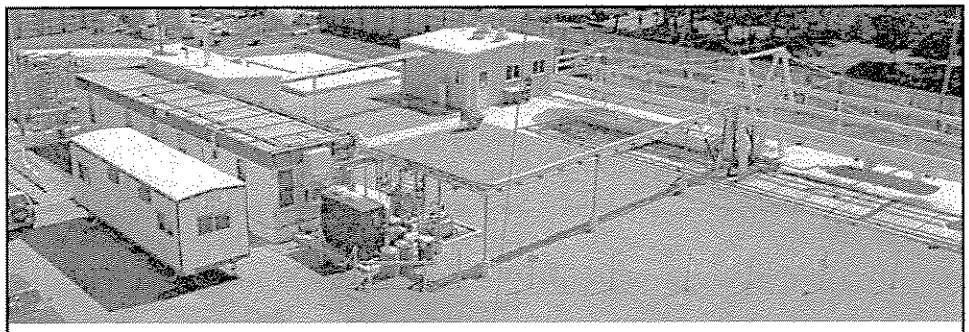

Bench Top Experimental Results

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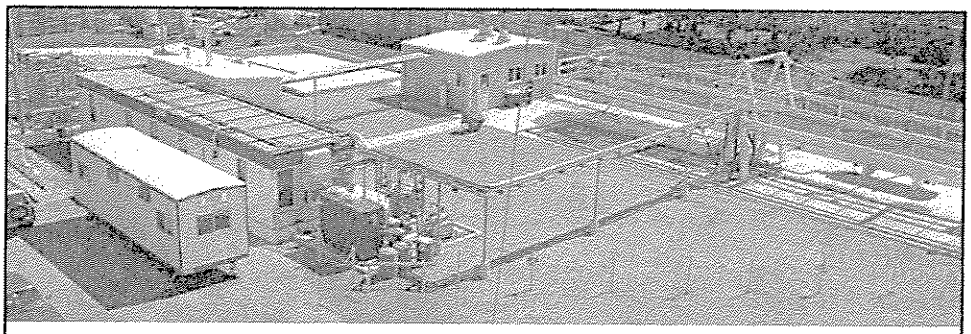

Water Cut Effects

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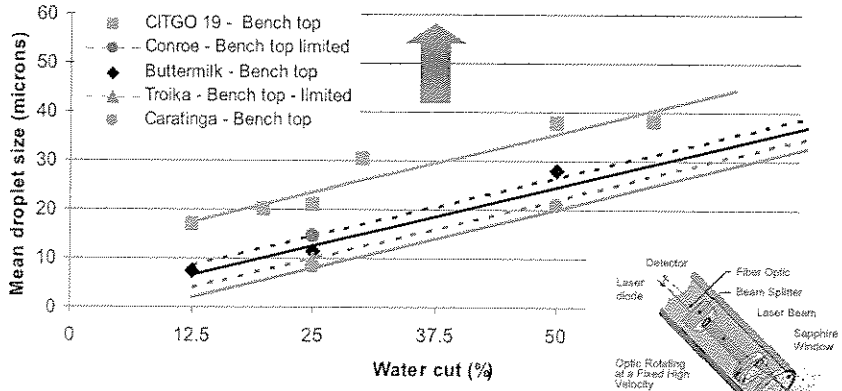
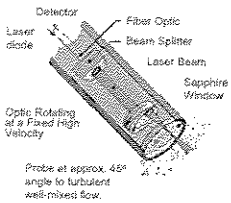
Mean Water Droplet Size by FBRM





- Based on 3 measurements
- Deviation = + / - 2 (microns)

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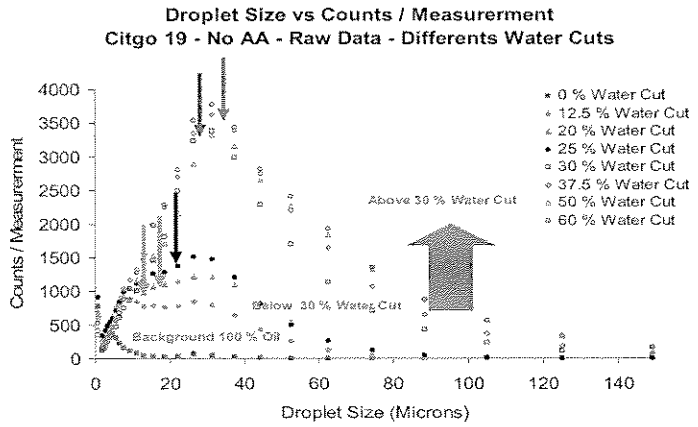
FBRM – CITGO 19



- Based on 3 measurements at = 70 °F
- Deviation = + / - 1 (microns)

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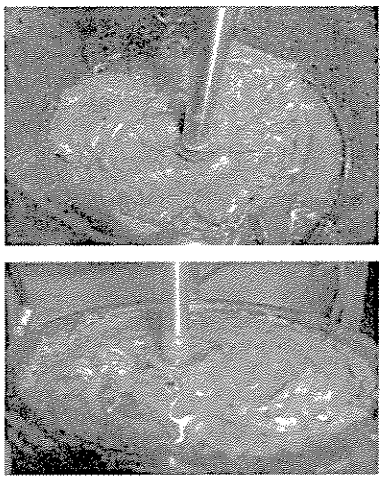
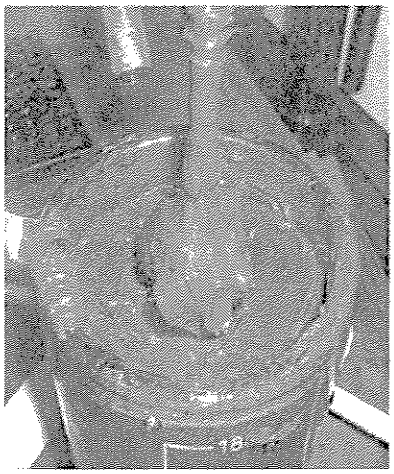
Inversion Points - Mousse

Troika at 65% and 83% water cut



Caratinga at 65 % Water cut



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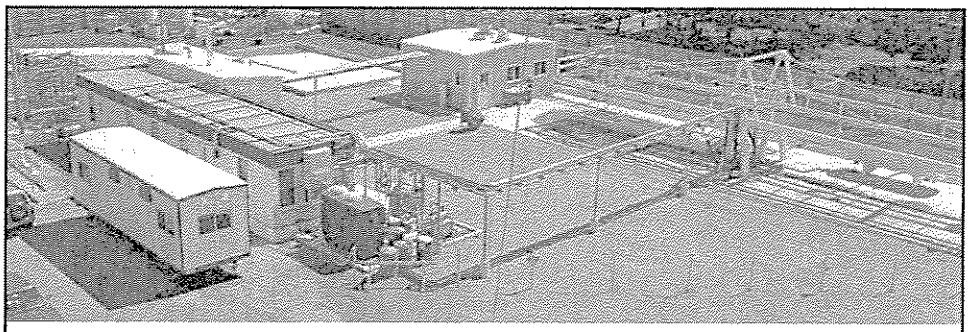

Fluid Properties Experiments & Effects on Water Droplet Size

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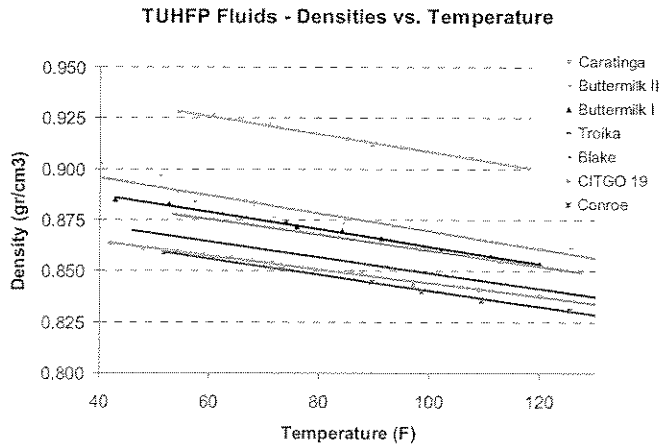
Oil densities - Hydrometer



- Based on 5 measurements at each temp.
- Deviation = + / - 0.02 (gr/cm³)

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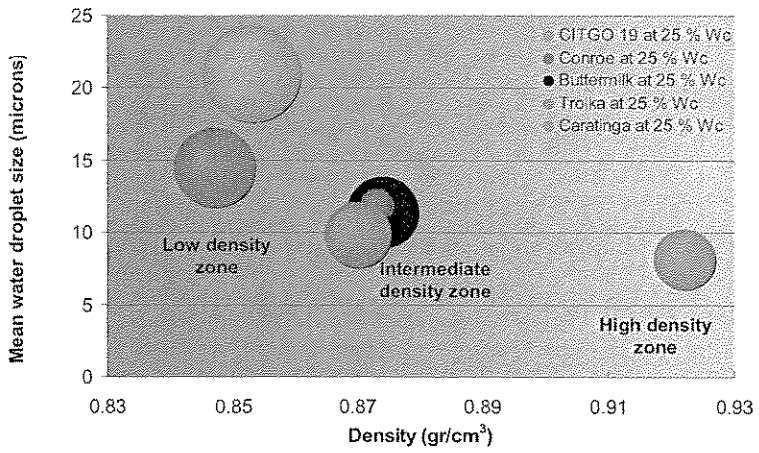
Density Effect on Water Droplet Size



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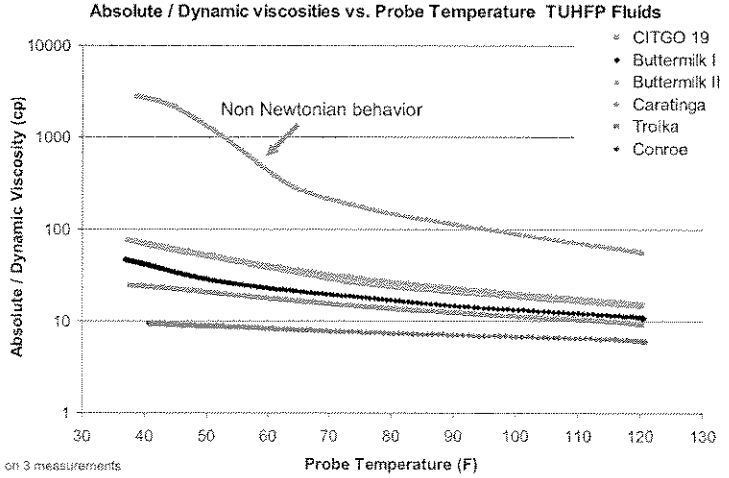
Viscosities - Acoustic Viscometer



• Based on 3 measurements
• Deviation = + / - 1 (cp)

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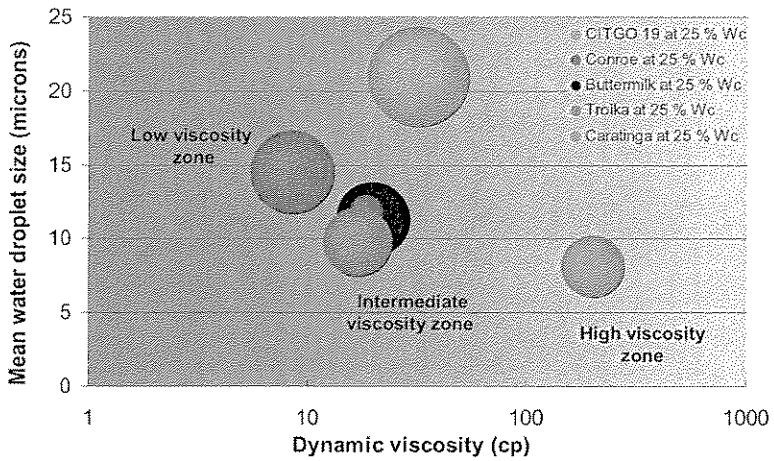
Viscosity Effect on Water Droplet Size



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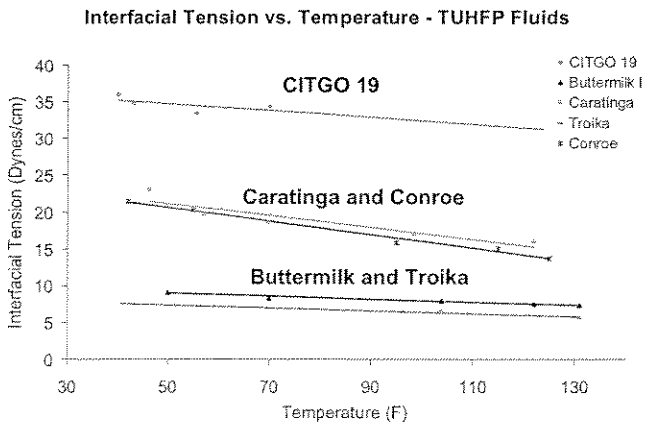
Interfacial Tension – De Nouy Ring



- Based on 5 measurements at each temp.
- Deviation = +/- 1.5 (dynes/cm)

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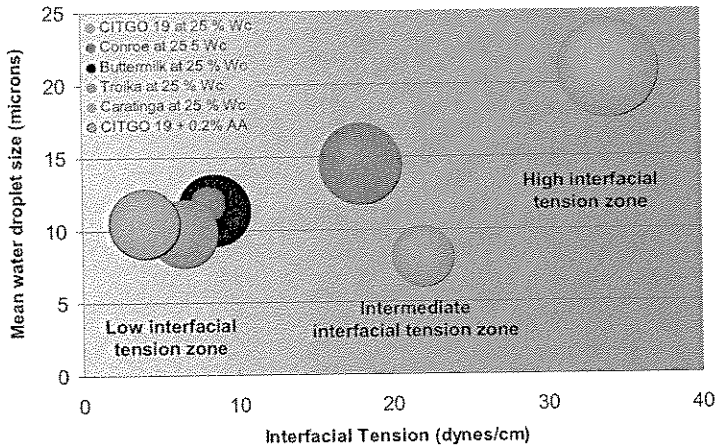
Interfacial Tension Effect on Water Droplet Size



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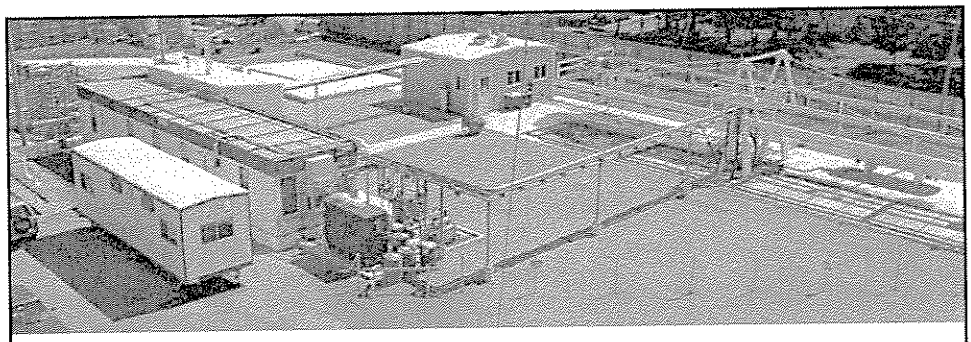

Anti-agglomerant and Salinity Effects

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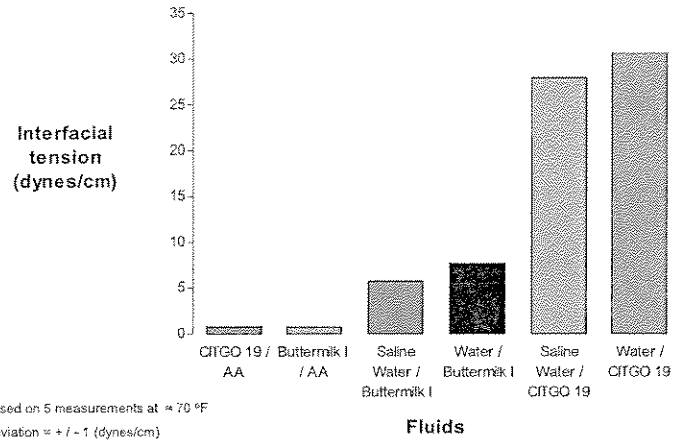
Anti-agglomerant and salinity effect on interfacial tension



- Based on 5 measurements at ≈ 70 °F
- Deviation ≈ + / - 1 (dynes/cm)
- Salinity 3.5 % - No further impact for 7% an 14%

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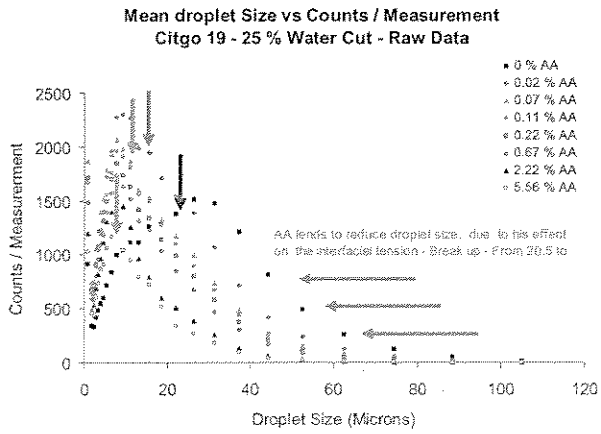

- Based on 3 measurements at ≈ 70 °F
- Deviation ≈ + / - 1 (microns)

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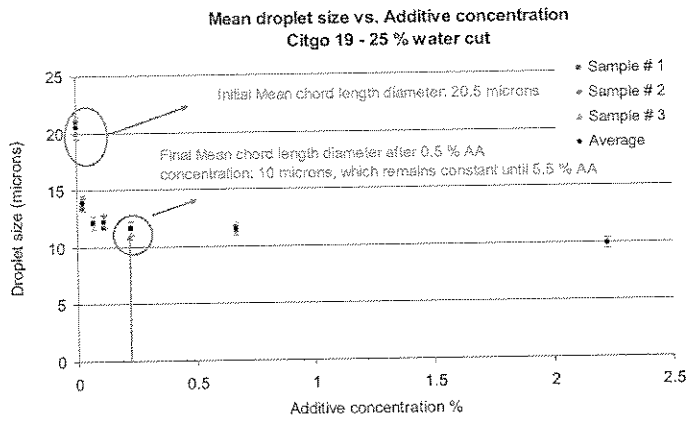
FBRM – CITGO 19



- Based on 3 measurements at ≈ 70 °F
- Deviation = + / - 1 (microns)

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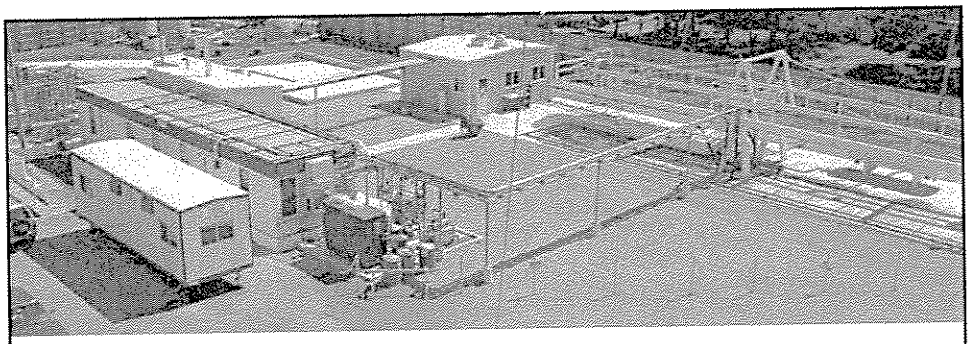

Shear Rate Experiments & Effect on Water Droplet Size

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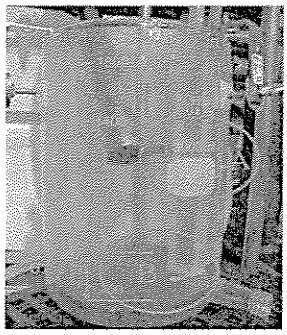
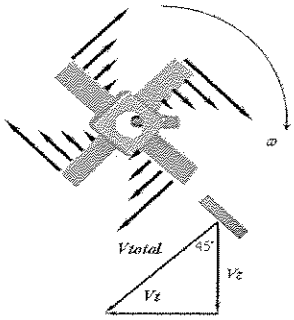
Bench Top Shear Rate Estimation

- Locations for maximum shear rate and impeller velocity profile

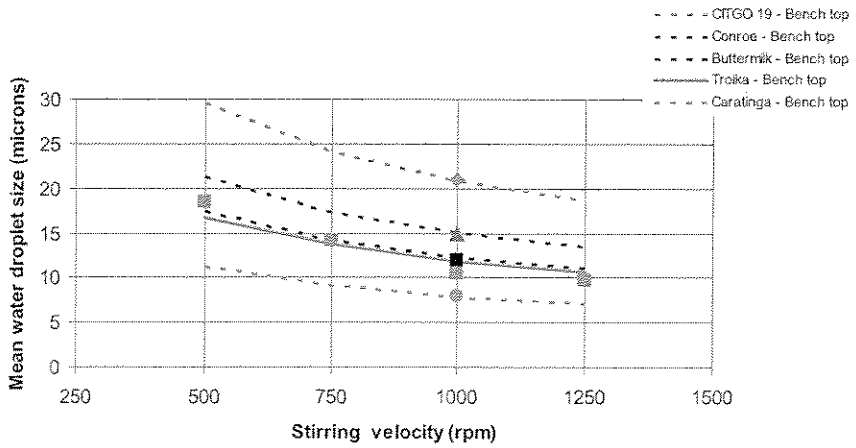
$$Vt = Vz = \frac{\omega \times d}{2} \qquad \delta = Vz \ / \ L = 140 \ \frac{1}{s}$$

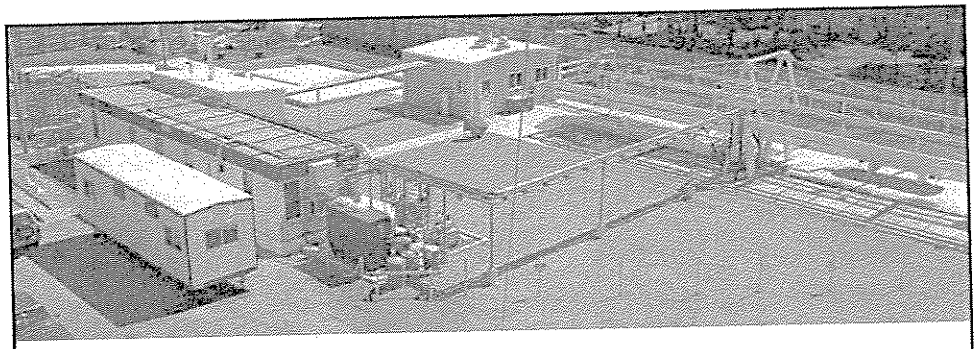




ω = 1000 rpm
d = 2 in
Vz= 8.7 ft/s
L= 0.75 in

Shear Rate Effect on Water Droplet Size – Bench Top





Droplet Size Model Comparisons

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THE UNIVERSITY of TULSA

Hinze Max. Droplet Size Model

- Hinze (1955), Fundamentals of hydrodynamic mechanism of splitting in dispersion process

1. Droplet size breakup model:

$$Nwe = \frac{\eta_c SD}{\sigma}$$ → Webber number

$$Nvi = \frac{\eta_d}{\sqrt{\rho_d \sigma D}}$$ → Viscosity number

Droplet breakup

$$Nwe > Nwe_{crit} = f(Nvi)$$

D: Droplet diameter
σ : Interfacial tension
η_d: Dispersed phase viscosity
ηc: Continuous phase viscosity
ρd : Dispersed phase density
S: Max. velocity
ρc : Continuous phase density
r: Impeller radius
N: mixer velocity
ε: Energy dissipation $=N^3 \times r^2$

2. Max. Droplet size model:

$$d_{max} = \frac{0.725}{\left(\frac{\rho_c}{\sigma}\right)^{3/5} (\varepsilon)^{2/5}}$$

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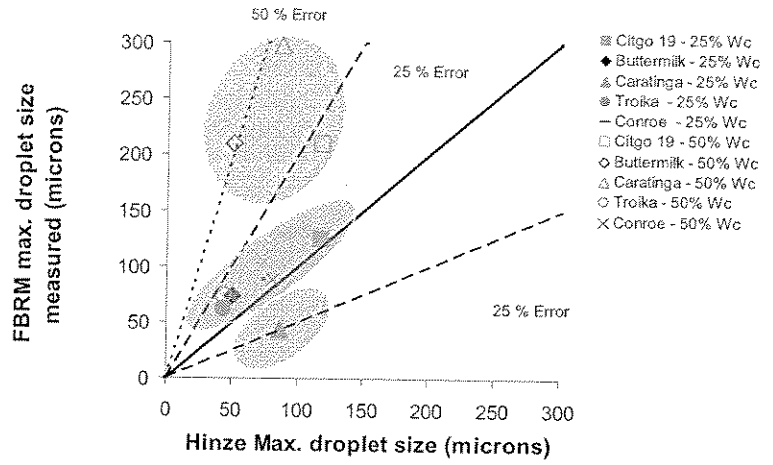
Hinze Max. Droplet Size Model



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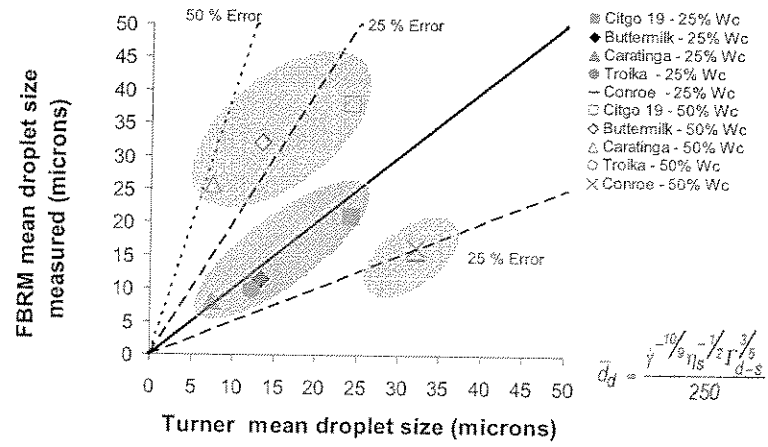
Turner Mean Droplet Size Model

- Turner (2005)



$$\bar{d}_d = \frac{\dot{\gamma}^{-10/9}\eta_s^{-2/3}\Gamma_{d-s}^{3/5}}{250}$$

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Droplet Stability Map

- Janssen et al (1994), Influence of dynamic interfacial properties on droplet breakup in simple shear flow
  - Droplet stability map

$$\Omega = \frac{\mu_c R G}{\sigma}$$

Ω: Capillary number
μc: Continues phase viscosity
R: Initial droplet radius
G: Local shear rate
ηd: Dispersed phase viscosity
σ : Constant and uniform interfacial tension

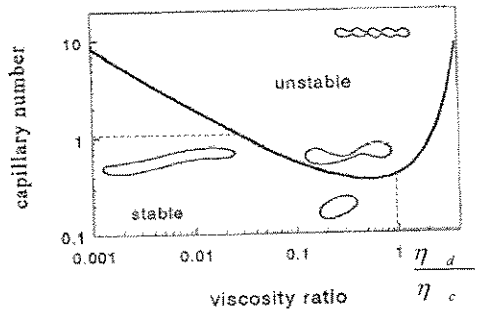

Figure 1. Droplet breakup in simple shear flow.
Drawn line: critical capillary number as a function of the viscosity ratio.

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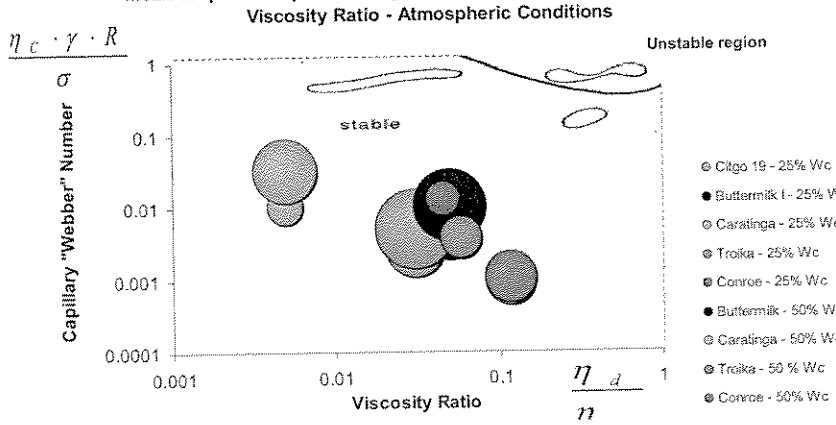
Droplet Stability Map

Mean droplet - Droplet Stability Map - Capillary "Webber"number vs. Viscosity Ratio - Atmospheric Conditions



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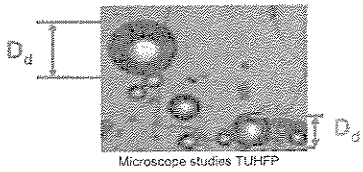
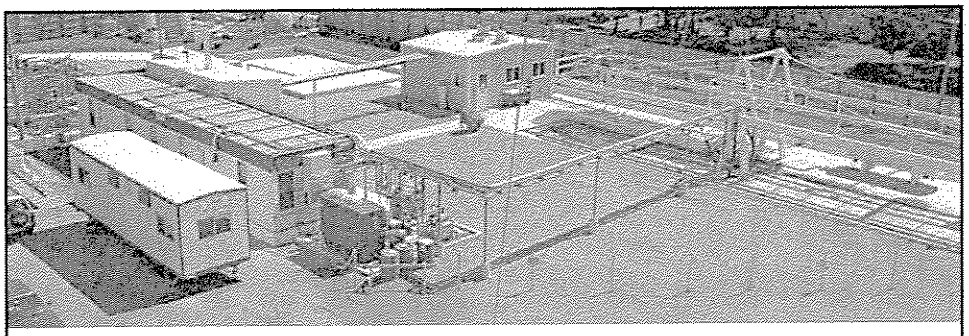
Variables Impacting Water Droplet Size

Large water droplet size	Small water droplet size
1. Fluid properties • High interfacial tension • Low oil viscosity and density	1. Fluid properties • Low interfacial tension • High oil viscosity and density
2. Operating parameter • Low shear rate or stirring velocity	2. Operating parameter • High shear rate or stirring velocity
3. Test conditions • High water cut • No surfactants • No salinity	3. Test conditions • Low water cut • Presence of surfactants • Salinity



Microscope studies TUHFP

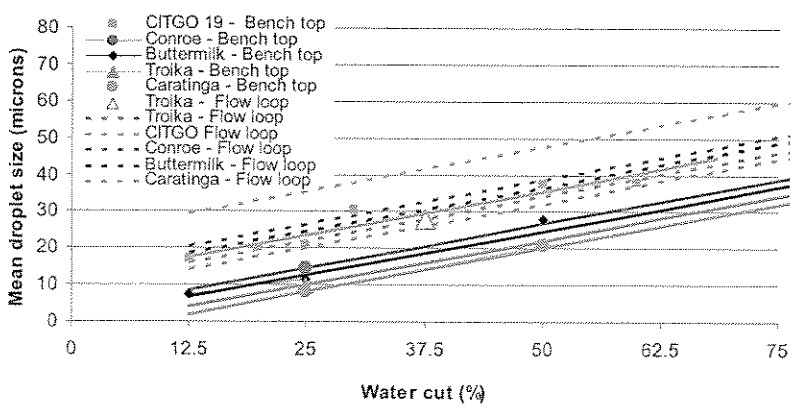


Flow Loop Experimental Results

Flow Loop Test Conditions

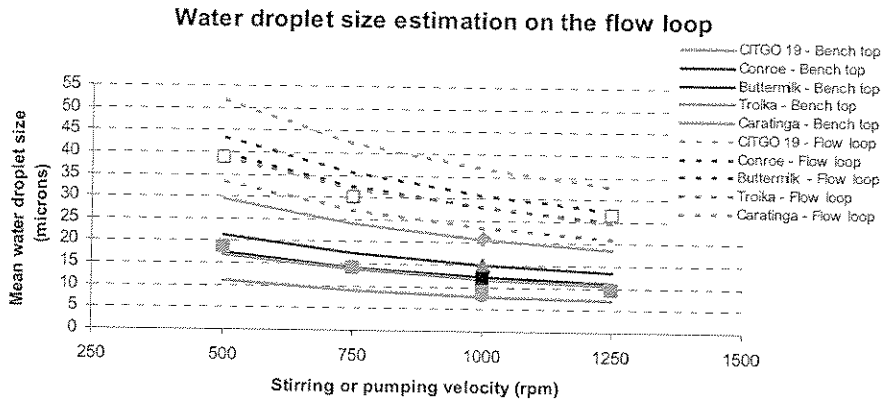
- Constant pressure: 2000 psi
- Cooling rate: 5 °F/hr
- Pumping
  - Cooling 16 hrs, Shut-in 6 hrs, and restart 2 hrs
- Pumping velocities
  - 1250, 750, and 500 rpm (7.2, 3.9, and 2.3 ft/s)
- Low pressure sample taken
  - Dispersed scenario verification and droplet size and shear rate estimation

Mean Water Droplet Size Estimation in Flow Loop



- Based on 3 measurements
- Deviation = + / - 1 (micron)

Shear Rate Effect Estimation on Water Droplet Size in Flow Loop



Plugging Classification

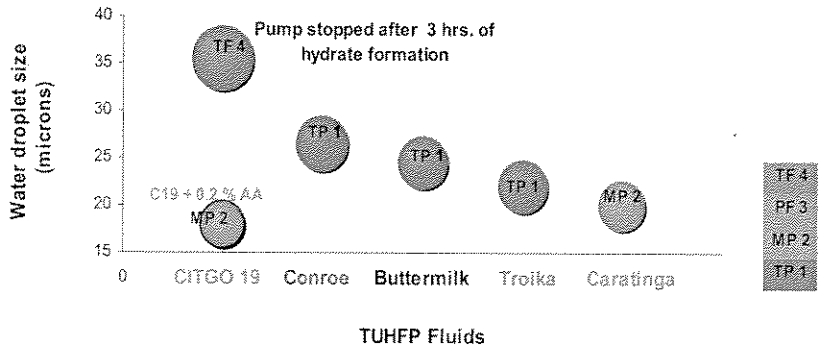
TF 4	Total Fail - Pump stopped or High Diff. Pressure - DPS > 50 PSI
PF 3	Partial Fail - Pump able to run - High Diff. Pressure - 25 < DPS < 50 PSI
MP 2	Marginal Pass - Intermediate Diff. Pressure - 10 > DPS > 25 PSI
TP 1	Total Pass - Low Diff. Pressure - DPS < 10 PSI

Flow Loop Test Results

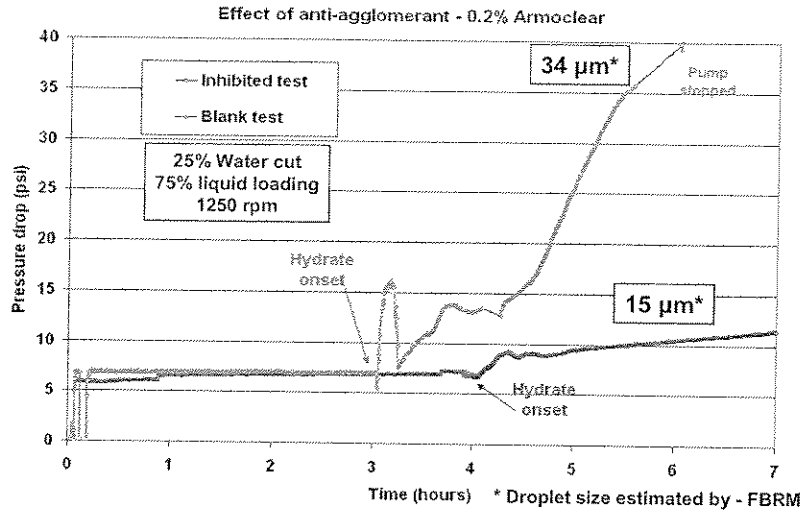
	Conditions							
	25% Wc				37.5% Wc			50% Wc
Fluids	1250 rpm 75% LL	1250 rpm 50% LL	750 rpm 75% LL	750 rpm 50% LL	1250 rpm 50% LL	750 rpm 50% LL	500 rpm 50% LL	750 rpm 50% LL
CITGO 19 + 0.2 % AA	MP Pass	?	?	?	?	?	?	?
Caratinga	MP Pass	Possible Pass	MP Pass	MP Pass	?	?	?	?
Troika	TP Pass	Possible Pass	Possible Pass	TP Pass CV	Possible Pass	TP Pass	TP Pass	TF 4 Fail CV TF 4 Fail CV 40 °/hr
Buttermilk	TP Pass	Possible Pass	Possible Pass	TP Pass TP Pass 3.5% salt	No more buttermilk			TF 4 Fail CV 3.5 % salt
Conroe	TP Pass	TP Pass	Possible Pass	TP Pass	MP Pass	PF 3 Fail	TF 4 Fail	TF 4 Fail at 1250 rpm
CITGO 19	TF 4 Fail	TF 4 Fail	TF 4 Fail	TF 4 Fail	Possible Fail	Possible Fail	Possible Fail	Possible Fail

Water Droplet Size Effect on Critical Plugging Water Cut

Mean water droplet size vs. Critical plugging water cut
25 % Wc - 1250 rpm - 75 % LL



Additive effect – CITGO 19



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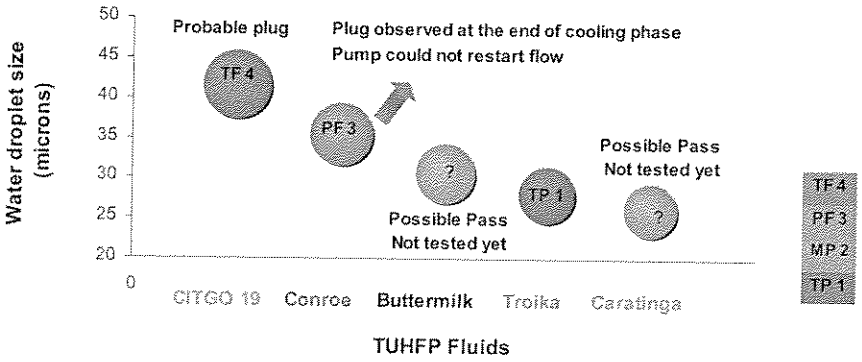
Water Droplet Size Effect on Critical Plugging Water Cut

Mean water droplet size vs. Critical plugging water cut
37.5 % Wc - 750 rpm - 50 % LL



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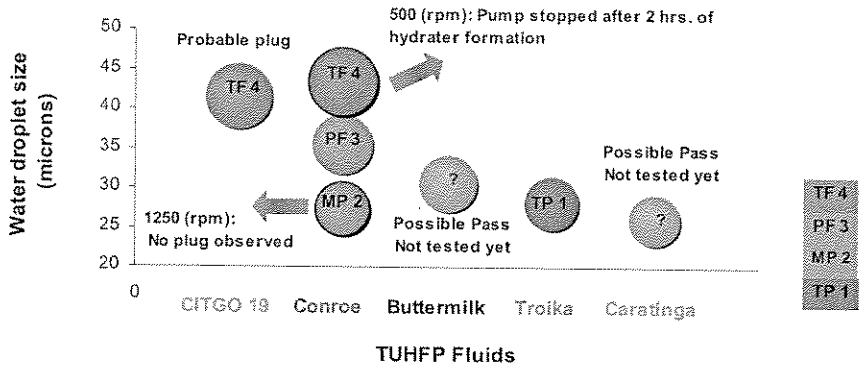
Water Droplet Size Effect on Critical Plugging Water Cut

Mean water droplet size vs. Critical plugging water cut
37.5 % Wc - 50 % LL



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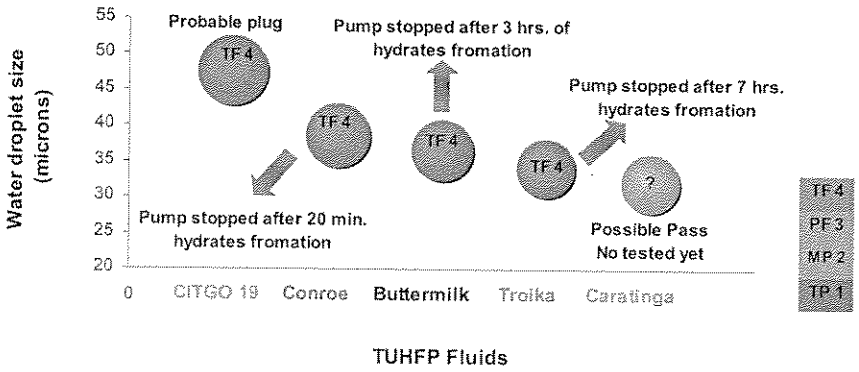
Water Droplet Size Effect on Critical Plugging Water Cut

Mean water droplet size vs. Critical plugging water cut
50 % Wc - 750 rpm - 50 % LL



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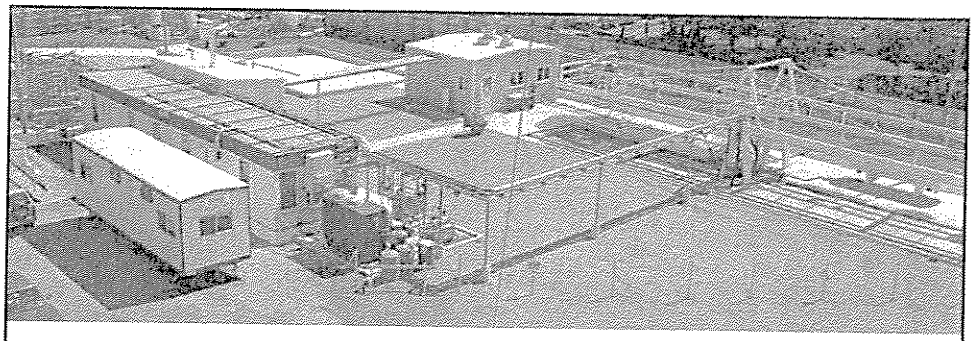

Hydrate Plugging Risk Indicator (HPRI)

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Hydrate Plugging Risk Indicator

1. Fluid properties measured at ambient conditions
2. Critical water cut has to be found for specific oil and system

Assumptions

- Negligible effect salinity
- No effect of pressure on interfacial tension and oil viscosity
- W/O emulsion

$$HPRI = \underbrace{\frac{\sigma_i \cdot \rho_d}{\eta_c \cdot \rho_c}}_{\text{W/O Fluid properties}} \cdot \frac{\overbrace{Wc}^{\text{Test conditions}}}{\gamma \cdot d_{pipe}} \cdot \underbrace{\frac{1}{Wc_{critical}}}_{\text{Critical water cut for hydrate plugging formation}}$$

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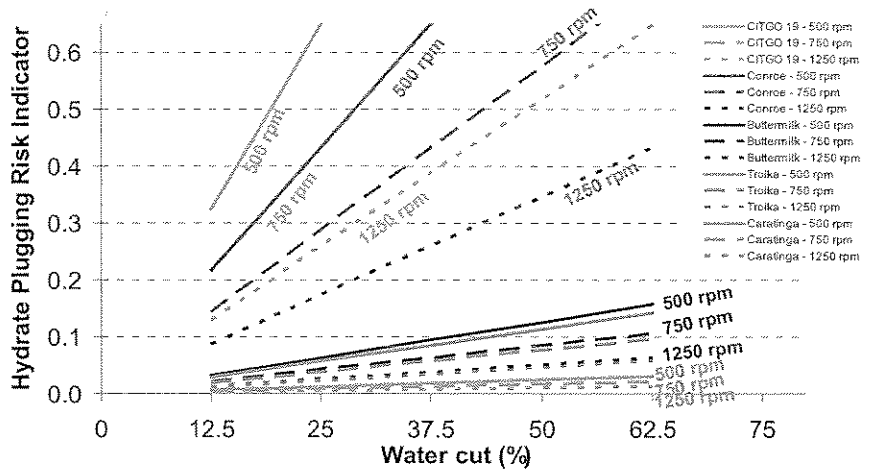
Hydrate Plugging Risk Indicator



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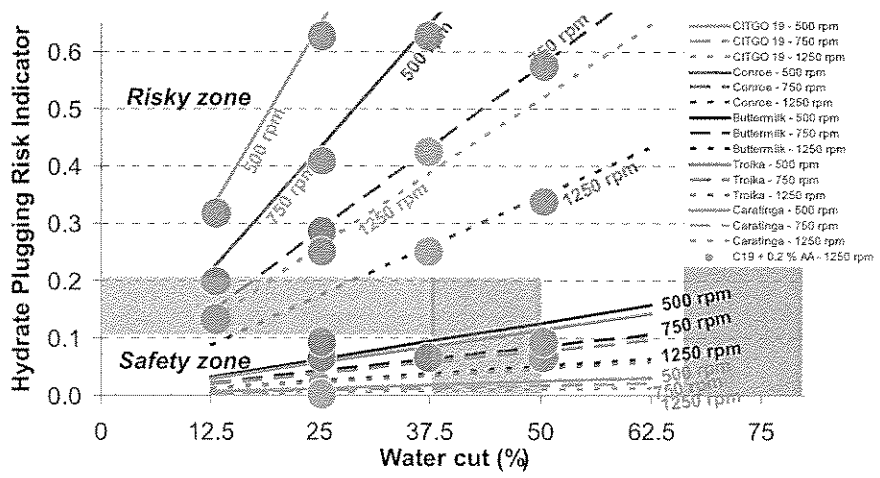
Hydrate Plugging Risk Indicator



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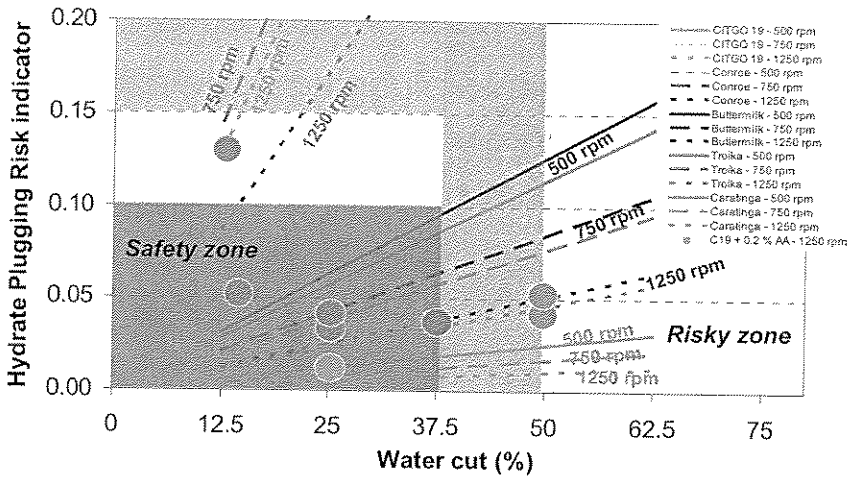
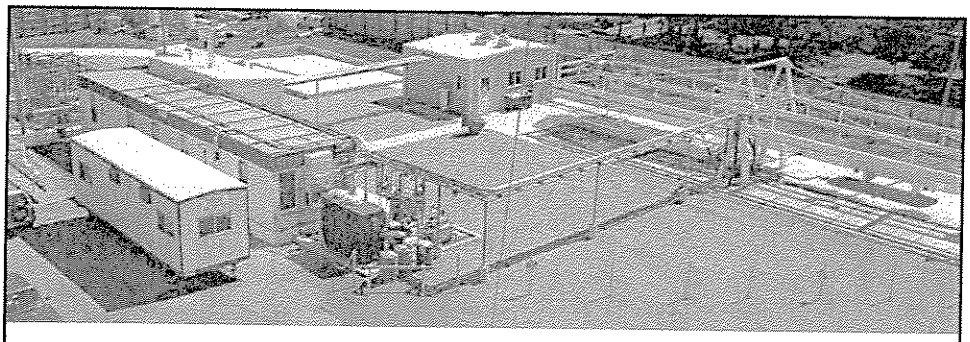
Hydrate Plugging Risk Indicator





Conclusions

Conclusions

- High water cuts form severe mousse which might contribute to plugging behaviors
  - Troika and Caratinga
- Hinze and Turner models underestimate droplet sizes
  - No water cut effect included
- Interfacial tension is reduced by:
  - Salinity (up to 3.5%)
  - Low concentration (0.1% vol.) of hydrate inhibitor

Conclusions

Large water droplet size	Small water droplet size
1. Fluid properties • High interfacial tension • Low oil viscosity and density	1. Fluid properties • Low interfacial tension • High oil viscosity and density
2. Operating parameter • Low shear rate or stirring velocity	2. Operating parameter • High shear rate or stirring velocity
3. Test conditions • High water cut • No surfactants • No salinity	3. Test conditions • Low water cut • Presence of surfactants • No salinity
High Plugging Risk	**Low Plugging Risk**

Conclusions

- D_d (Flow loop) ~ 2.5 D_d (bench)
  - Based on lower shear rate (Troika)
- Proposed hydrate plugging risk indicator
  - Based on fluid properties, water cut, critical water cut, pipe diameter and shear rate

$$HPRI = \frac{\sigma_i \cdot \rho_d}{\eta_c \cdot \rho_c} \cdot \frac{Wc}{\gamma \cdot d_{pipe}} \cdot \frac{1}{Wc_{critical}}$$

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Future Work

- Complete Caratinga flow loop tests
- Establish the effect of high pressure and low temperature on viscosity, interfacial tension, and water droplet size
  - PVM-FBRM probe
  - High pressure rheometer
  - High speed video
- Better estimation of shear rate fields in the flow loop
  - CFD (Computational Fluid Dynamics)

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Future Work

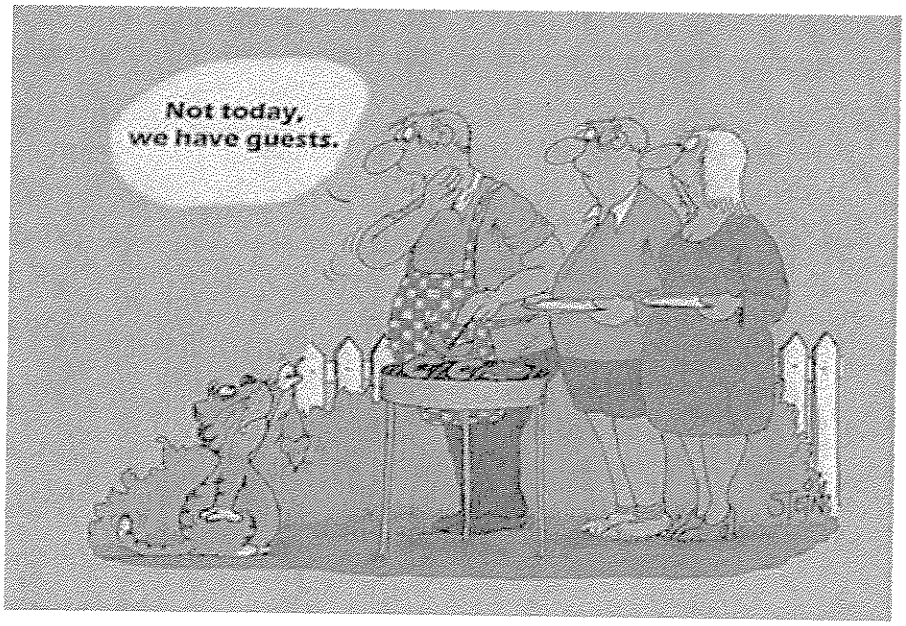
- Hydrate plugging parameter
  - Validate with other oils
  - Experiments with other pipe diameters
  - Include liquid loading effect

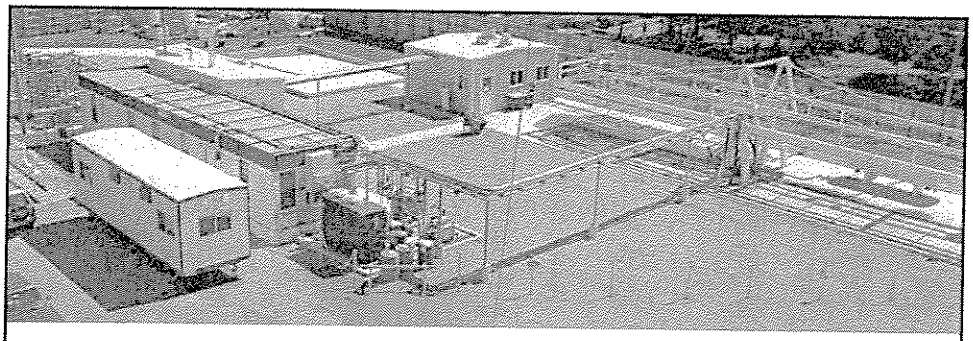
Dispersion characterization studies

Questions

?

Lunch





Porosity and Permeability Studies

Lissett Barrios

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Outline

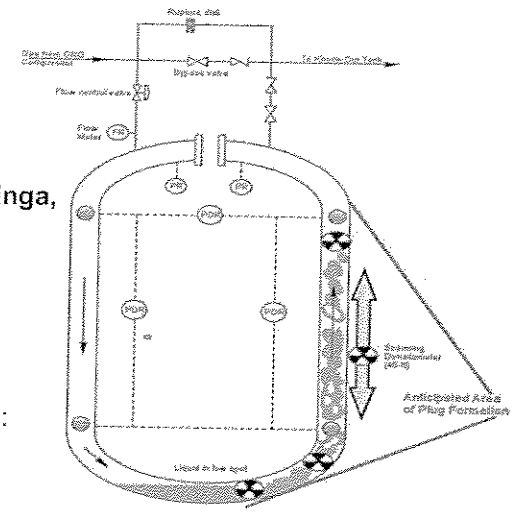
- Low Spot Test
  - Permeability and Porosity
  - Summary
- Steady-State Test
  - Permeability and Porosity
  - Summary
- Remediation and Hydrate Plug Characterization (New Approach)
- Dissociation Modeling
  - Dissociation Results (Simulator)
  - New dissociation Model (Depressurization)

Background

- Plug Characterization in previous low spot tests (permeability calculations)

Background-Low Spot Test

- Estanga (2006)
  - Length Leg = 65 ft
  - Pmax = 1000 psi
  - Gas: Tulsa NG
  - Fluids: **Water, Caratinga, Buttermilk, Citgo19**
  - Fluid Condition:
    - Dispersed
    - Segregated
  - Inclination Angle: -8°
  - Gas Restart Velocity*:
    - Low= 0.15 ft/s
    - High= 0.25 ft/s



Background-Plug Severity

- Estanga (2006)

Plug permeability was approximated by Darcy's law

$$k = v\mu \frac{dl}{dp}$$

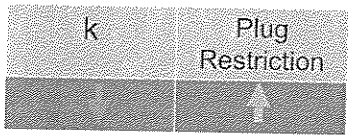
Where,

v = gas velocity

μ = gas viscosity

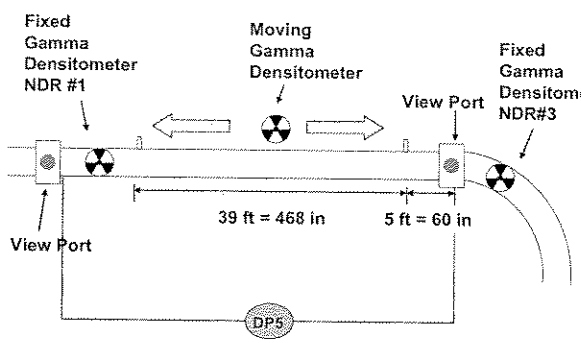
dl = plug length

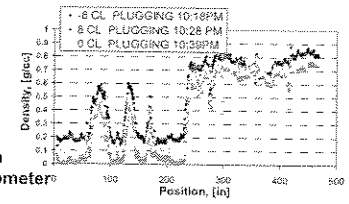
dp= pressure drop because of plug



Background-Plug Length

- Estanga (2006)





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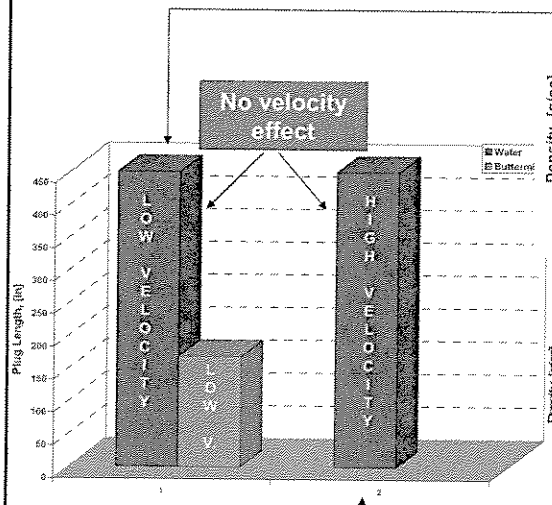
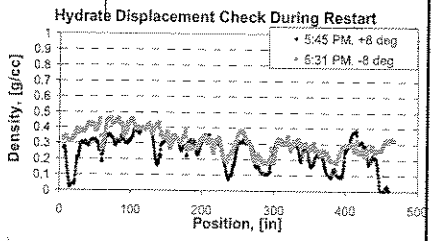
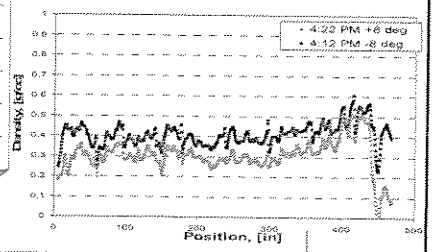
Background-Plug Length







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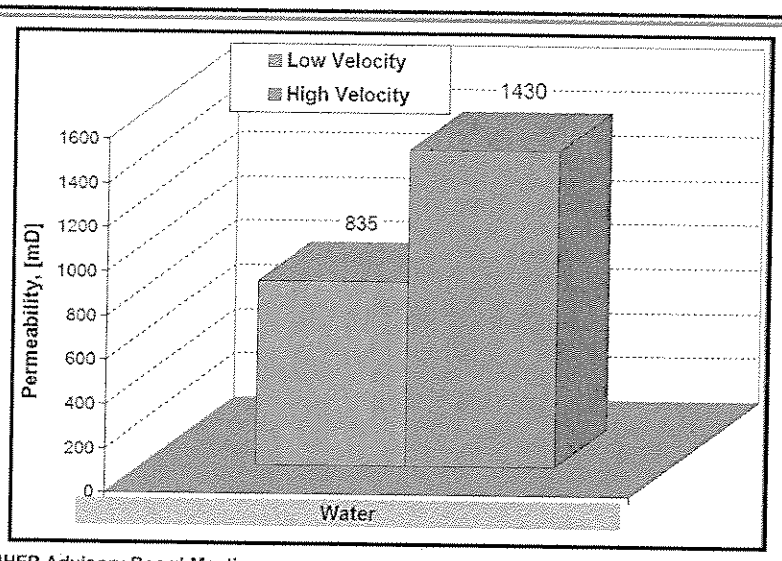
Water-NG: Gas Permeability



Gas Permeability

- Estanga (2006)

Tests #	Permeability [mD]	Fluid	%LL	%WC	Condition	Velocity
LS1	835	Water-NG	25		Water	Low
LS2	1430	Water-NG	25		Water	High
LS3	749	CA-NG-Water	25	50	Dispersed	Low
LS4	2892	CA-NG-Water	25	50	Dispersed	High
LS5	1057	CA-NG-Water	25	50	Segregated	Low
LS6	923	CA-NG-Water	25	50	Segregated	High
LS7	735	Citgo19-NG-Water	25	50	Dispersed	Low
LS8	2248	Citgo19-NG-Water	25	50	Dispersed	High

Summary

- Pressure Drop data for permeability calculations are not reliable for low spot tests
- Gamma scans yield accurate plug length measurements
- Permeability calculation requires either accounting for gravity term or drainage of liquids

New Approach-Porosity

- Plug Porosity Calculation

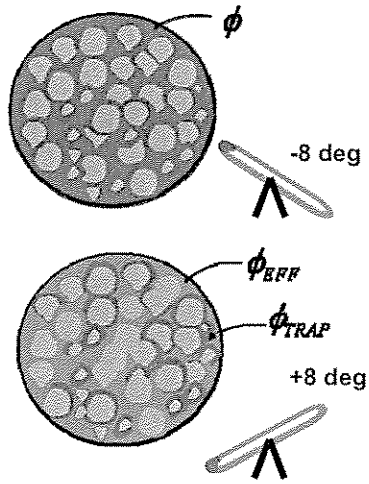
$$\phi = \frac{V_p}{V_{BULK}}$$

$$\rho_{BULK} = \rho_{MIX}\phi + \rho_{HYD}(1-\phi)$$

Moving Gamma PVTSim

$$\phi = \frac{\rho_{BULK} - \rho_{HYD}}{\rho_{MIX} - \rho_{HYD}}$$

$$\phi = \phi_{EFF} + \phi_{TRAP}$$



Objective

- Porosity calculations for low spot tests

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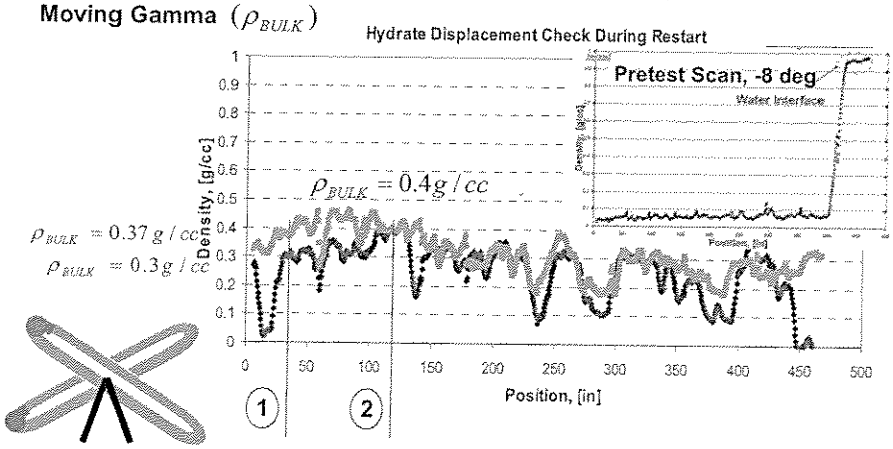
Porosity- Low Spot Test

- NG-Water (25%LL, Low Velocity)

Moving Gamma (ρ_{BULK})



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Porosity- Low Spot Test

- NG-Water (25%LL, Low Velocity)

PVTSim (ρ_{HYD})

LS1 **NG-Water Low Velocity** **EOS = SRK Peneloux**

Flash to
1000.00 psia
45.00 °F

	Liquid	Aqueous	Hyd-I	Hyd-II	
Mole%	0.01	57.17	38.78	4.04	
Weight%	0.02	57.37	38.52	4.09	
Volume	1.63	0.29	0.31	0.32	ft³/lb-mol
Volume%	0.03	55.05	40.65	4.27	Mix Hyd
Density	0.6033	1.0055	0.9142	0.9241	g/cm³ 0.91509727
Z Factor	0.3005	0.0530	0.0577	0.0582	

ρ_{HYD}

Porosity- Low Spot Test

- NG-Water (25%LL, Low Velocity)

✓ **+ 8 deg (Assuming just gas in the porous space)**

$$\rho_{BULK} = \rho_{HYD}(1-\phi_T) + \rho_G \phi_T$$

Unknown??

$$\rho_{BULK} = 0.30 g/cc$$

$$\rho_G = 0.06 g/cc$$

$$\phi_T = \frac{\rho_{BULK} - \rho_{HYD}}{\rho_G - \rho_{HYD}} = 0.72$$

Porosity- Low Spot Test

- NG-Water (25%LL, Low Velocity)
  - ✓ -8 deg (gas + water in the porous space)

$$\rho_{BULK} = \rho_{HYD}(1-\phi_{TOTAL}) + \rho_g \phi_{EFF} + \rho_w \phi_{TRAP}$$

$$\rho_{BULK} = 0.37 g/cc \qquad \phi_T = \phi_{EFF} + \phi_{TRAP}$$

$$\rho_g = 0.06 g/cc$$

$$\phi_T = 0.72$$

$$\phi_{EFF} = 0.65$$

$$\phi_{TRAP} = 0.07$$

Objective (Steady-State Test)

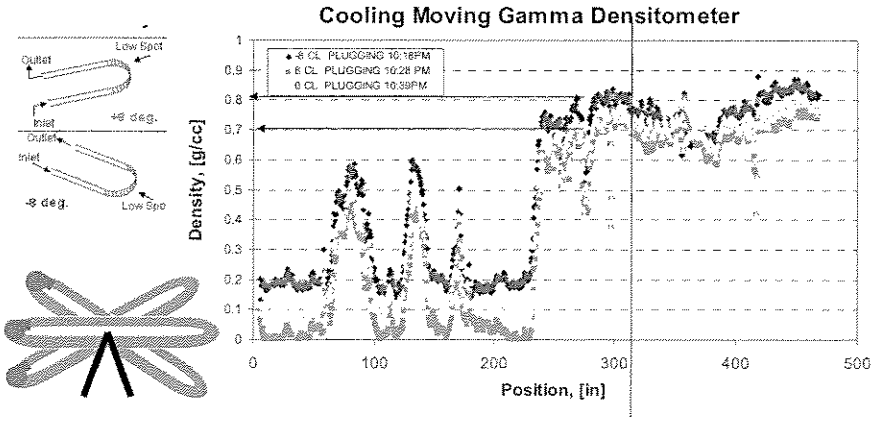
- Plug Characterization in steady-state test (permeability and porosity measurements)

Steady-State Test

- Constant Pressure: 2000 psi
- Gas: Tulsa NG
- Fluids: **Conroe**
- **Pumping: 750 rpm**
- Fluid Condition:
  - ✓ Dispersed
- Inclination Angle: 0°
- Cooling Rate: 5 ° F/hr (16hours)
- Shut-in: 6 hour
- Restart: Pumping 750 rpm

Porosity- Steady-State Test

- Conroe-NG-Water (50%LL, 50%WC, 750rpm)



Porosity- Steady-State Test

- Conroe-NG-Water (50%LL, 50%WC, 750rpm)

PVTSim (ρ_{HYD})

HYD2007-039CO10 Conroe 50%WC, 50%LL EOS = SRK Peneloux

Flash to
1914.00 psia
50.00 °F

	Vapor	Liquid	Hyd-I	Hyd-II	
Mole%	2.27	14.41	73.24	10.08	
Weight%	1.38	44.79	47.22	6.61	
Volume	2.29	2.17	0.31	0.31	ft³/lb-mol
Volume%	8.32	50.10	36.51	5.06	Mix Hyd.
Density	0.1180	0.6349	0.9185	0.9275	g/cm³ 0.91960164
Z Factor	0.7997	0.7586	0.1088	0.1096	

ρ_{HYD}

Porosity- Steady-State Test

- Conroe-NG-Water (50%LL, 50%WC, 750rpm)

✓ **- 8 deg**

$$\rho_{BULK} = \rho_{HYD}(1-\phi_{TOTAL}) + \rho_{MIX}\phi_{TOTAL}$$

$$\rho_{BULK} = 0.8 g/cc$$

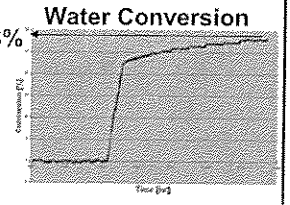
$$\rho_{MIX} = 0.63 g/cc \times 0.64 + 1.00 g/cc \times 0.36$$

$$\rho_{MIX} = 0.77 g/cc$$

$$\phi_{TOTAL} = 0.78 = \phi_{EFF} + \phi_{TRAP}$$

Water Conversion

28%



$\rho_{OIL} = 0.63 g/cc \longrightarrow \phi_{TOTAL} = 0.44 = \phi_{EFF} + \phi_{TRAP}$

$\rho_{MIX} = 1 g/cc \longrightarrow$ **Negative Values**

Porosity- Steady-State Test

- Conroe-NG-Water (50%LL, 50%WC, 750rpm)
  - ✓ **+ 8 deg**

$$\rho_{BULK} = \rho_{HYD}(1-\phi_{EFF}-\phi_{TRAP}) + \rho_{GAS}\phi_{EFF} + \rho_{MIX}\phi_{TRAP}$$

$$\rho_{BULK} = 0.71 g/cc$$
$$\rho_G = 0.12 g/cc$$

Mix=Oil + Water

$\phi_{TOTAL} = 0.78$
$\rho_{MIX} = 0.77 g/cc$
$\phi_{EFF} = 0.14$
$\phi_{TRAP} = 0.64$

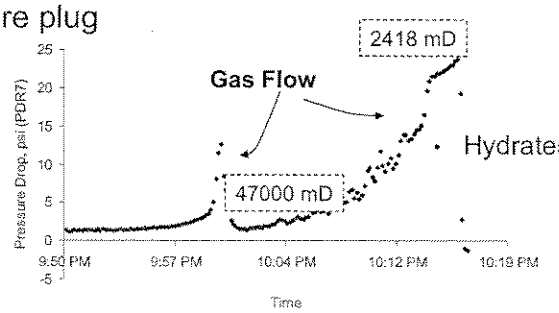
Mix=Oil

$\phi_{TOTAL} = 0.44$
$\rho_{OIL} = 0.63 g/cc$
$\phi_{EFF} = 0.17$
$\phi_{TRAP} = 0.26$

Permeability

- Conroe-NG-Water (50%LL, 50%WC, 750rpm)
  - Severe plug

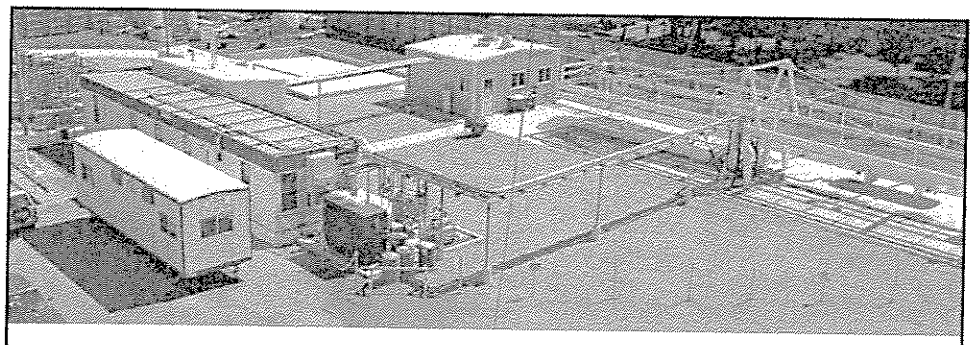
$$k = v\mu \frac{dl}{dp}$$



- Hydrates compacting?
- Is it gas flow only? Gas rate?

Summary

- Gamma scan yields porosity calculations
- Permeability calculation requires drainage of liquids to obtain stable pressure drop readings
- To get accurate porosity calculations the ρ_{MIX} needs to be measured after drained process



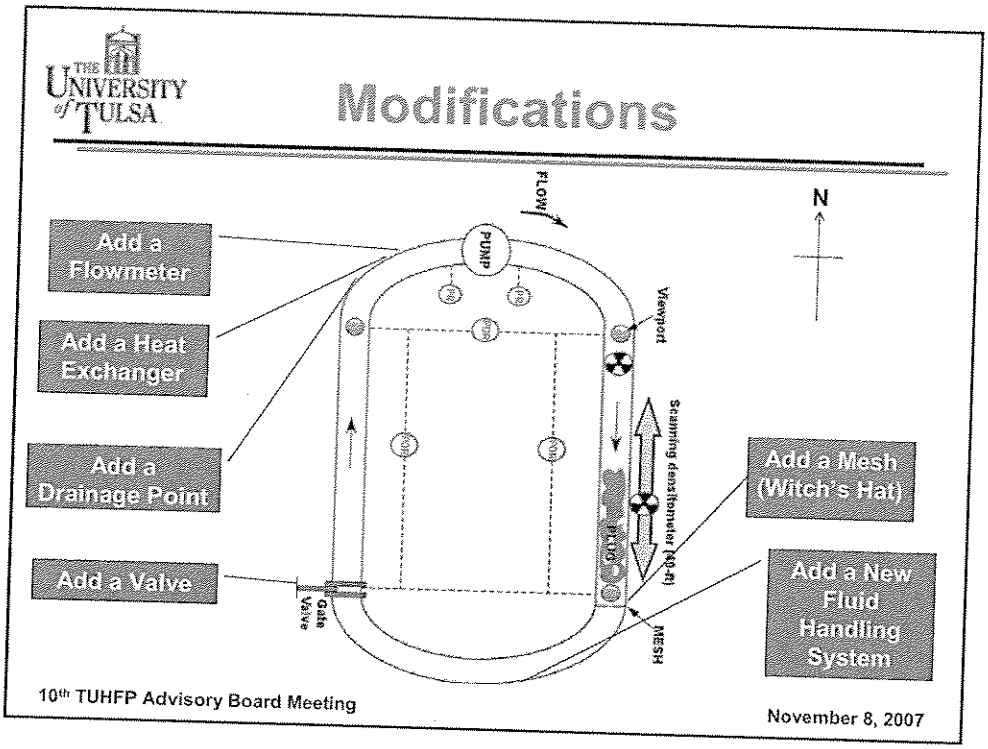
Remediation and Hydrate Plug Characterization (New Approach)

Objectives

- Investigate plug characteristics (permeability and porosity) & dissociation methods such as depressurization, wall heating and thermodynamic inhibitors

Tasks

- Characterization
  - Plug characteristics virtually unknown
    - Gas vs. liquid dominated systems
  - Density, permeability, porosity measurements on real hydrate plugs
- Remediation
  - Dissociation methods will be evaluated
    - Heating, depressurization, methanol, MEG
  - Comparisons with current modeling tools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Modifications
Add a Flowmeter
Add a Heat Exchanger
Add a Drainage Point
Add a Valve
Add a Mesh (Witch's Hat)
Add a New Fluid Handling System
FLOW
PUMP
N
Viewport
Scanning densitometer (X-R)
MESH
Gate Valve
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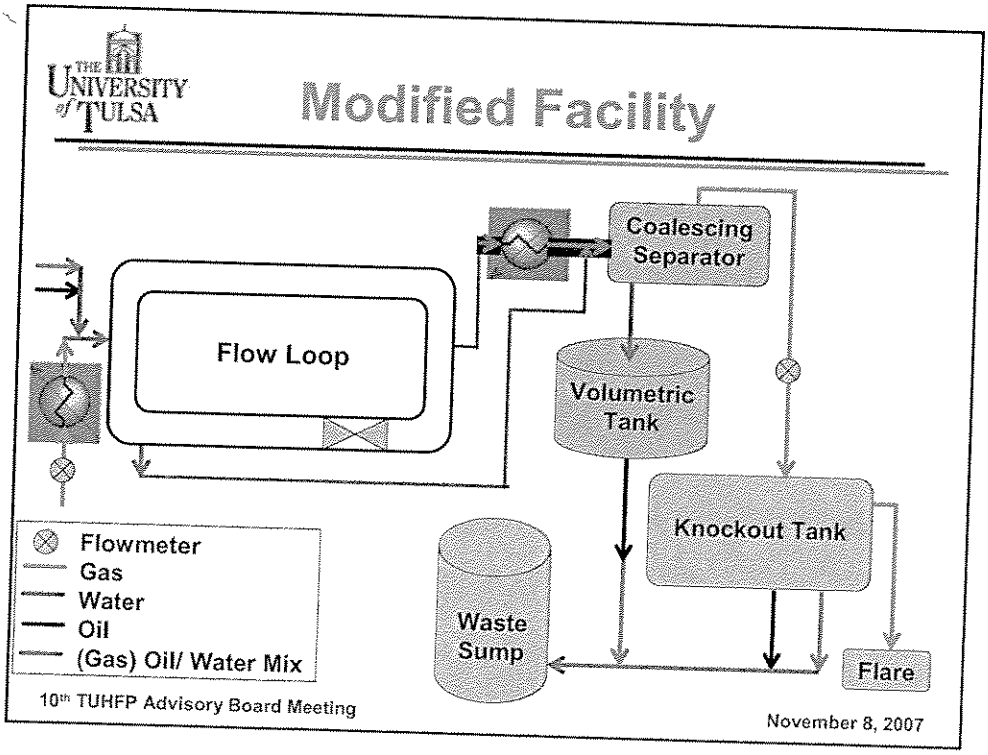
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Modified Facility
Flow Loop
Coalescing Separator
Volumetric Tank
Knockout Tank
Waste Sump
Flare
Flowmeter
Gas
Water
Oil
(Gas) Oil/ Water Mix
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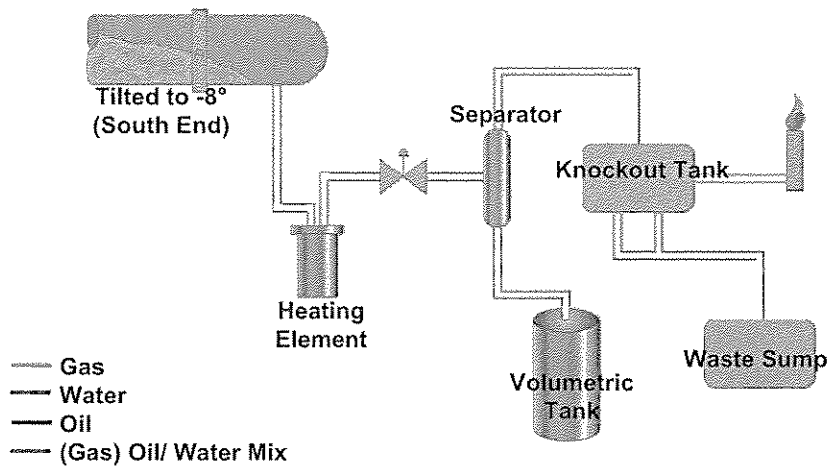
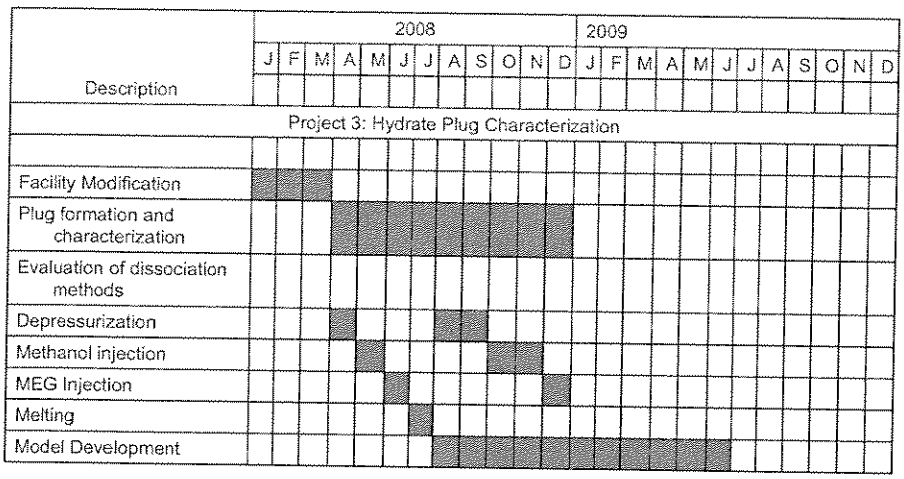
Facility Modifications



Plug Characterization Test

- Hydrate Formation (pumping at 0°)
- Drain Free Liquids (tilt to -8° and +8°)
  - Density scans (porosity, plug length)
  - Record the Volume of the Drained Oil , Water and Gas
- Measure ΔP of the Plug (gas at -8°)
  - Collect liquids from effective porosity
- Density Scans of the Plug (at +8°, 0°, -8°)
  - Porosity calculation
- Dissociation

Plug Characterization Test



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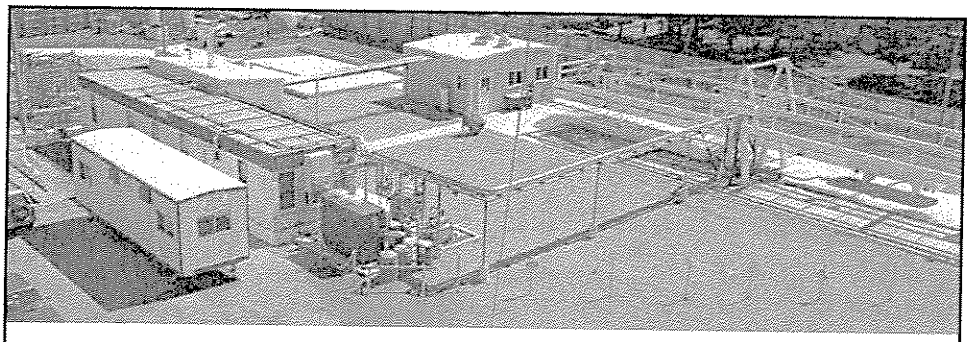

Dissociation Modeling

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Objectives

- Compare plug dissociation results from simulator for wall heating with existing data
- Develop plug dissociation methods or model for depressurization, wall heating and thermodynamic inhibitors

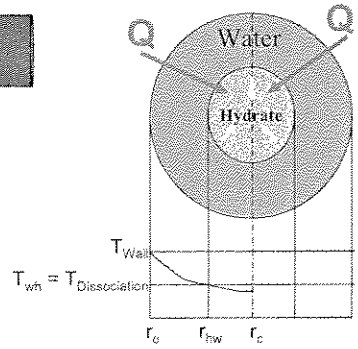
Dissociation Simulator

- Ivanic (2006)

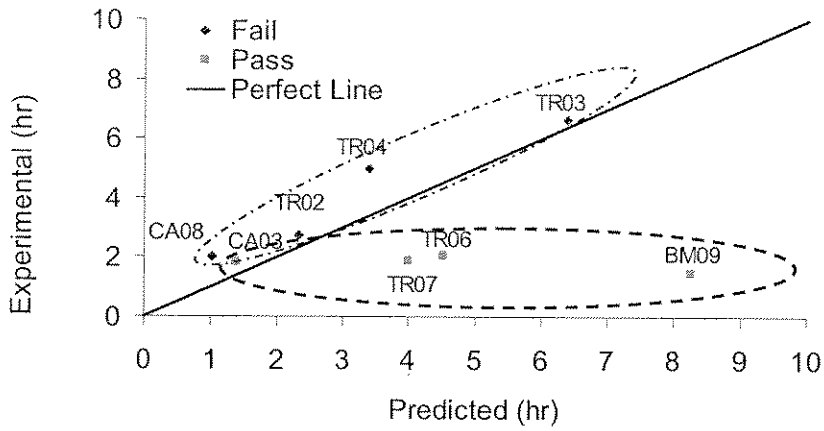
Assumption:

Plugs homogeneously fill the pipeline

$$\frac{\partial T}{\partial t} = \alpha \left[\frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial r^2} \right]$$

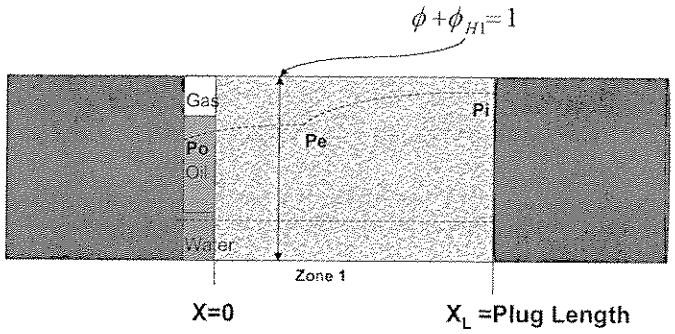


Dissociation Results



New Dissociation Model

- Hydrate Dissociation by Depressurization
  - Initial Conditions

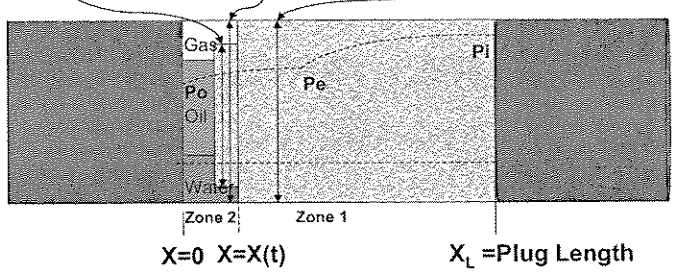


New Dissociation Model

- Hydrate Dissociation by Depressurization:

$$\phi_P = \phi_V + \phi_2$$
$$\phi_{HT} = \phi_2 + \phi_{H2}$$
$$\phi_V + \phi_{HT} = 1$$

$\phi + \phi_{H1} = 1$ $\qquad$ $\phi + \phi_{H1} = 1$



Dissociation Modeling

- Conservation Equations (Hydrate Zone)
  - ✓ **Oil** $\quad 0 = \frac{\partial}{\partial t}(\phi \rho_o S_o) \qquad S_w + S_o + S_g = 1$
  - ✓ **Water** $\quad \dot{m}_w = \frac{\partial}{\partial t}(\phi \rho_w S_w)$
  - ✓ **Gas** $\quad -\nabla \rho_g \vec{V}_g + \dot{m}_g = \frac{\partial}{\partial t}(\phi \rho_g S_g)$
- Conservation Equation (Hydrate Zone + Void Space)
  - ✓ **Hydrate** $\quad \dot{m}_H = \frac{\partial}{\partial t}[\rho_H (1 - \phi_P)]$

Dissociation Modeling

- Darcy's Equation: $$q_f = -\frac{k_f A}{\mu_f}\left(\frac{\partial P}{\partial x} + \rho_f g \sin\alpha\right)$$

  - ✓ **Oil** $$0 = \phi \frac{\partial S_o}{\partial t} \qquad S_o \approx const$$
  - ✓ **Water** $$\frac{\dot{m}_w}{\rho_w} = \phi \frac{\partial S_w}{\partial t}$$
  - ✓ **Gas** $$-\frac{\partial}{\partial x}\left[\left(\frac{-k_g}{\mu_g}\left(\frac{\partial P}{\partial x} + \rho_g g \sin\alpha\right)\right)\right] + \frac{\dot{m}_g}{\rho_g} = \phi \frac{\partial S_g}{\partial t}$$

Dissociation Modeling

- Energy Balance (Void Space)

Internal Energy

$$\frac{\partial}{\partial t}\left[S_w \rho_w U_w + S_o \rho_o U_o + S_g \rho_g U_g\right] =$$
$$= \left(K \frac{\partial^2 T}{\partial x^2} + \frac{1}{r}\frac{\partial}{\partial r}\left(Kr \frac{\partial T}{\partial r}\right)\right) - \frac{\partial}{\partial x}\left(\rho_g h_g V_g\right)$$

Thermal Conductivity Enthalpy

University of Tulsa Confidential

Dissociation Modeling

- Energy Balance (Hydrate Zone)

Heat Capacity Internal Energy

$$\frac{\partial}{\partial t}\left[(1-\phi)\rho_H C_H T + \phi S_w \rho_w U_w + \phi S_o \rho_o U_o + \phi S_g \rho_g U_g\right] =$$
$$= \left(K\frac{\partial^2 T}{\partial x^2} + \frac{1}{r}\frac{\partial}{\partial r}\left(Kr\frac{\partial T}{\partial r}\right)\right) - \frac{\partial}{\partial x}\left(\rho_g h_g V_g\right)$$

Thermal Conductivity Enthalpy

Dissociation Modeling

- Hydrate Dissociation:

Kinetic Model (Kim 1987)

$$\dot{m}_g = C_B A_P \left[P_e(T) - P\right]$$

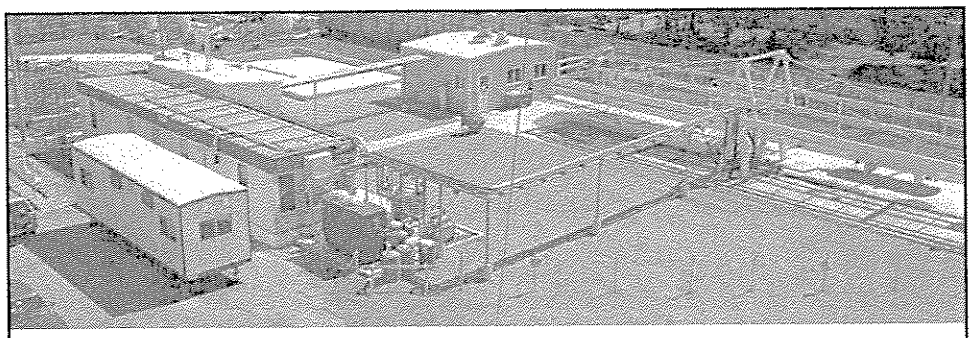
$$C_B = k\exp\left(-\frac{\Delta E}{RT}\right)$$

$$A_P = \sqrt{\frac{\phi}{2k}}$$

Future Work

- Modification of the flow loop
- Plug characterization test
- Plug dissociation test
- Develop dissociation model

Questions



Hydrate Management Program

Continuation Proposal

10th TUHFP Advisory Board Meeting

November 8, 2007

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Objectives

- Continue investigation of hydrate formation
  - Focus on LL & flow patterns and plugging during production and restart conditions
- Investigate plug characteristics & dissociation methods
  - Depressurization, wall heating and thermodynamic inhibitors
- Investigate transient water displacement in a jumper configuration and effect with hydrates
  - Comparison to models

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Scope of Work

- Project 1: Risk assessment of hydrate plugging during steady-state operations
- Project 2: Risk assessment of hydrate plugging during restart operations
- Project 3: Remediation and hydrate plug characterization

Project 1

- Steady-state operations
  - Important variables identified in previous CTR's
    - Oil-water flow patterns (rate, liquid loading)
    - Oil viscosity, brine salinity
  - Conduct systematic experiments
    - Focus on these key variables
    - Gather slurry flow data
  - Perform simulations of past and new experiments

Project 2

- Restart operations
  - Past experiments indicated strong effect of flow patterns and salinity
  - Transient experiments in jumper-like configuration will be performed
    - Focus on water displacement
    - With and without hydrates
    - With and without inhibitors
  - Comparisons with simulations
    - Validate current tools for prediction of water displacement
    - Collaboration with Scanpower

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Project 3

- Remediation
  - Plug characteristics virtually unknown
    - Gas vs. liquid dominated systems
  - Density, permeability, porosity measurements on real hydrate plugs
  - Dissociation methods will be evaluated
    - Heating, depressurization, methanol, MEG
  - Comparisons with current modeling tools

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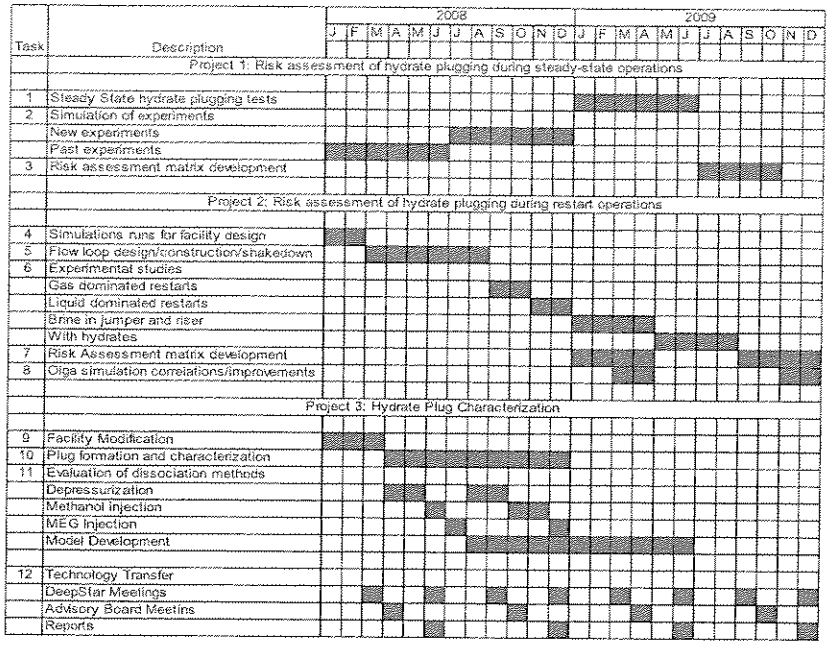
Phase III Gantt Chart



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Deliverables

- Extended database of hydrate experiments (steady-state and transient)
  - Parametric studies, slurry flow, plug properties
- Comparisons with simulation tools
  - Hydrate formation simulations
  - Transient flow simulations
  - Plug dissociation simulations
- Better understanding for better engineering

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Continuation Proposal Summary

- Two year project
- Three Studies
  - Steady State Operations
  - Restart
  - Remediation
- Projected Fee of $50,000/year
- Legal Document
  - Addendum II
- Addendum/Proposal/Invoice mailed late November
- Start Date of January 2008

Open Discussion / Issue Bin

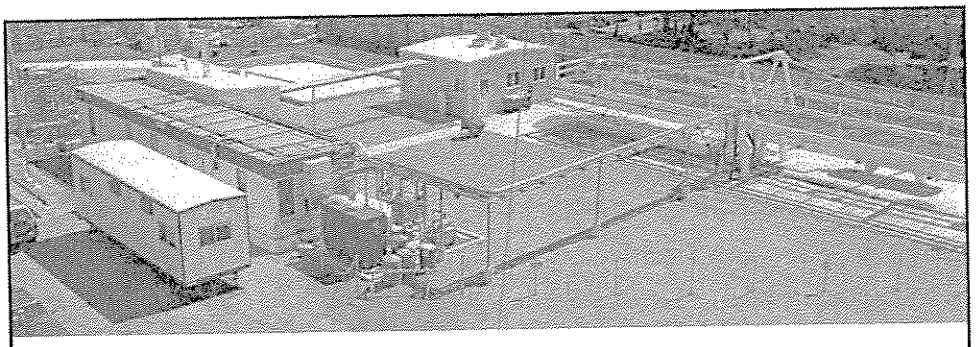
"ANY OTHER NAGGING PAINS?"

Inventory Status (55-gal drums)

- Buttermilk I exhausted
  - Buttermilk II contaminated (10 bbl)
  - Suggest to dispose of the sample
- Troika 8
- Caratinga 18
- Conroe 3
- Blake 20
- Arnold 32 (needs reconditioning)

Model Oils

- Citgo Sentry series being phased out
  - Additive packages in lube oils
  - Are they the same for different viscosity grades?



Closing Remarks

Mike Volk

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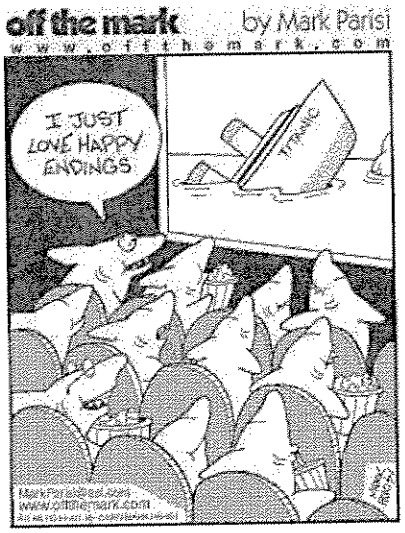
November 8, 2007

Hope You Enjoyed the Show!



Future Meetings

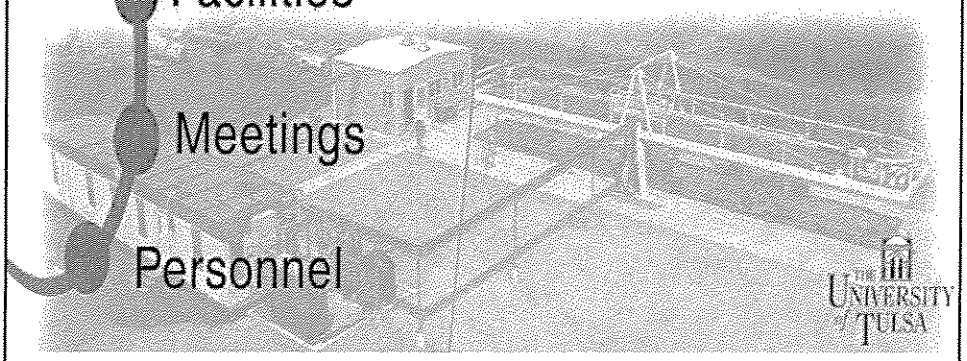
- DeepStar Meetings
  - December 6, 2007
  - March 2008
- TUHFP Advisory Board Meeting
  - Held in Houston
  - Following DeepStar Meeting
  - 12:30 – 5:00 PM

Hydrate Flow Performance JIP

THE UNIVERSITY OF TULSA RESEARCH PROGRAM

http://www.tuhfp.utulsa.edu

- Research
- Facilities
- Meetings
- Personnel



Adjourn

Would you mind closing
the door on the way out?
We're trying to
be classy in Connecticut.