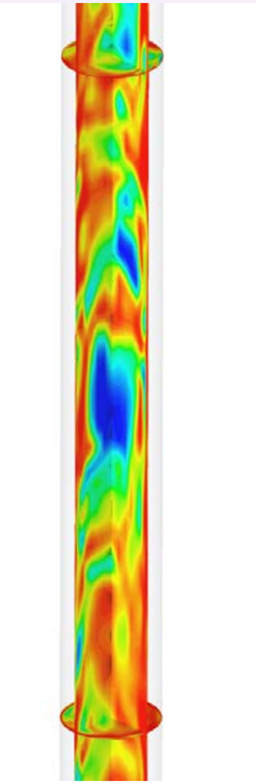
Experimental Investigation and Performance Evaluation of Models Applied to Worst-Case-Discharge Calculations



Source: http://response.restoration.noaa.gov/index.php

New Orleans, LA – Workshop #1 - Jan 29, 2016

LSU Team – Principal Investigators

Paulo Waltrich, PhD.
Assistant Professor

PhD in Petroleum Engineering

Richard Hughes, PhD.
Professional in Residence

PhD in Petroleum Engineering

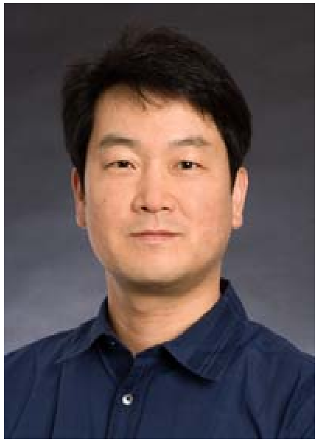
Mayank Tyagi, PhD.
Associate Professor

PhD in Mechanical Eng.

LSU Team – Principal Investigators

Wesley Williams, PhD.
Professional in Residence

PhD in Nuclear Engineering



Seung Kam, PhD.
Associate Professor

TEXAS
The University of Texas at Austin

PhD in Petroleum Eng.

LSU Team – Post-Doc and Graduate Students

Muhammad Zulqarnain, PhD.

Post-Doc

PhD in Petroleum Engineering

Woochan Lee, MSc.

PhD Graduate Student

MSc. in Petroleum Engineering

Renato Coutinho, MSc.

PhD Graduate Student

MSc. in Chemical Engineering

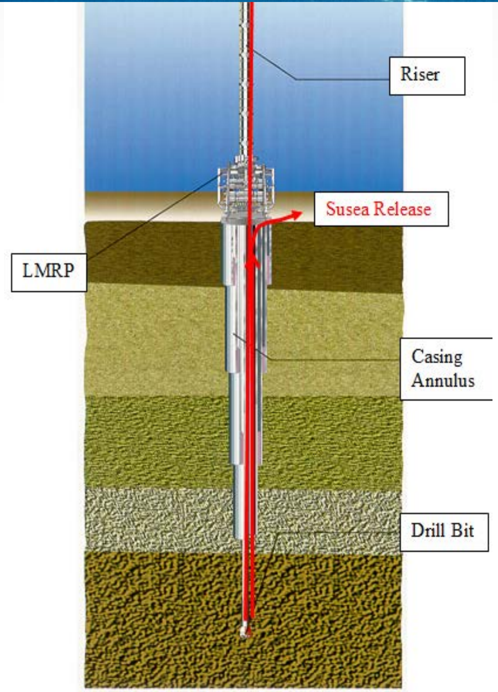
Outline

- ✓ Overview of project Objectives and Deliverables
- ✓ Literature Review Findings and Conclusions
- ✓ Description of Base Cases for comparison study *(Dr. Muhammad Zulqarnain)*
- ✓ CFD model description *(Dr. Mayank Tyagi)*
- ✓ Methodology for Comparison of Wellbore Flow models Applied for WCD Calculation
- ✓ Results for WCD Rates for Different Wellbore Flow Models
- ✓ Experimental work progress
- ✓ Conclusions
- ✓ Next Steps

Project Motivation

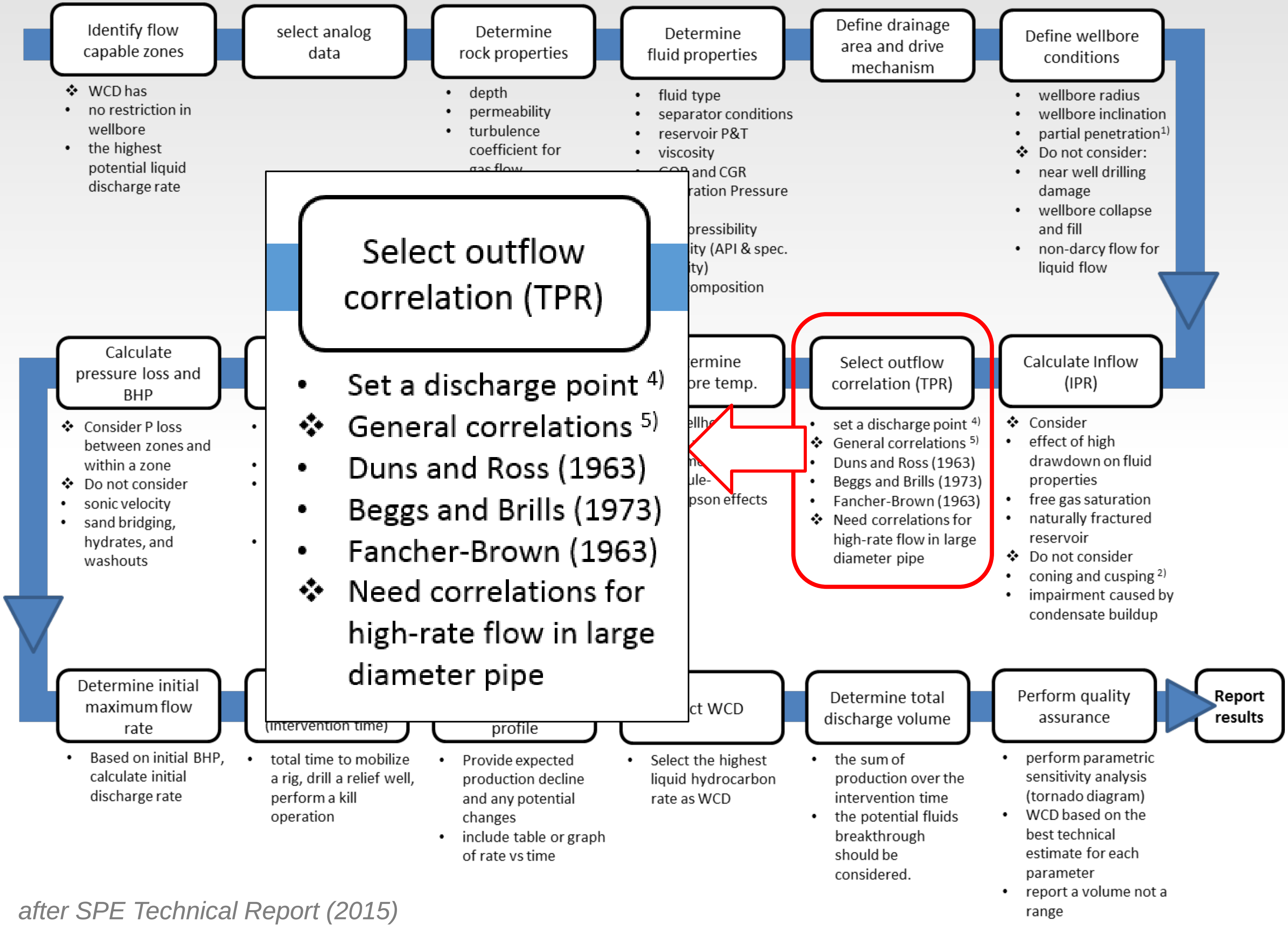
- **Blowouts** Happen!
- For **effective contingency** plans, we need **accurate oil spill predictions**!
- For accurate predictions, **we need reliable models**!

Source: http://response.restoration.noaa.gov/index.php



Source: TAMU – Pemex Offshore Drilling

Statement of the Problem



Identify flow capable zones
- ❖ WCD has
- no restriction in wellbore
- the highest potential liquid discharge rate

select analog data

Determine rock properties
- depth
- permeability
- turbulence coefficient for gas flow

Determine fluid properties
- fluid type
- separator conditions
- reservoir P&T
- viscosity
- and CGR
- ration Pressure
- pressibility
- ity (API & spec.
- ity)
- omposition

Define drainage area and drive mechanism

Define wellbore conditions
- wellbore radius
- wellbore inclination
- partial penetration[1)]
- ❖ Do not consider:
- near well drilling damage
- wellbore collapse and fill
- non-darcy flow for liquid flow

Calculate Inflow (IPR)
- ❖ Consider
- effect of high drawdown on fluid properties
- free gas saturation
- naturally fractured reservoir
- ❖ Do not consider
- coning and cusping [2)]
- impairment caused by condensate buildup

Select outflow correlation (TPR)
- set a discharge point [4)]
- ❖ General correlations [5)]
- Duns and Ross (1963)
- Beggs and Brills (1973)
- Fancher-Brown (1963)
- ❖ Need correlations for high-rate flow in large diameter pipe

Select outflow correlation (TPR)
- Set a discharge point [4)]
- ❖ General correlations [5)]
- Duns and Ross (1963)
- Beggs and Brills (1973)
- Fancher-Brown (1963)
- ❖ Need correlations for high-rate flow in large diameter pipe

ermine
ore temp.
- ellh
- ule-
- pson effects

Calculate pressure loss and BHP
- ❖ Consider P loss between zones and within a zone
- ❖ Do not consider
- sonic velocity
- sand bridging, hydrates, and washouts

Determine initial maximum flow rate
- Based on initial BHP, calculate initial discharge rate

(intervention time)
- total time to mobilize a rig, drill a relief well, perform a kill operation

profile
- Provide expected production decline and any potential changes
- include table or graph of rate vs time

ct WCD
- Select the highest liquid hydrocarbon rate as WCD

Determine total discharge volume
- the sum of production over the intervention time
- the potential fluids breakthrough should be considered.

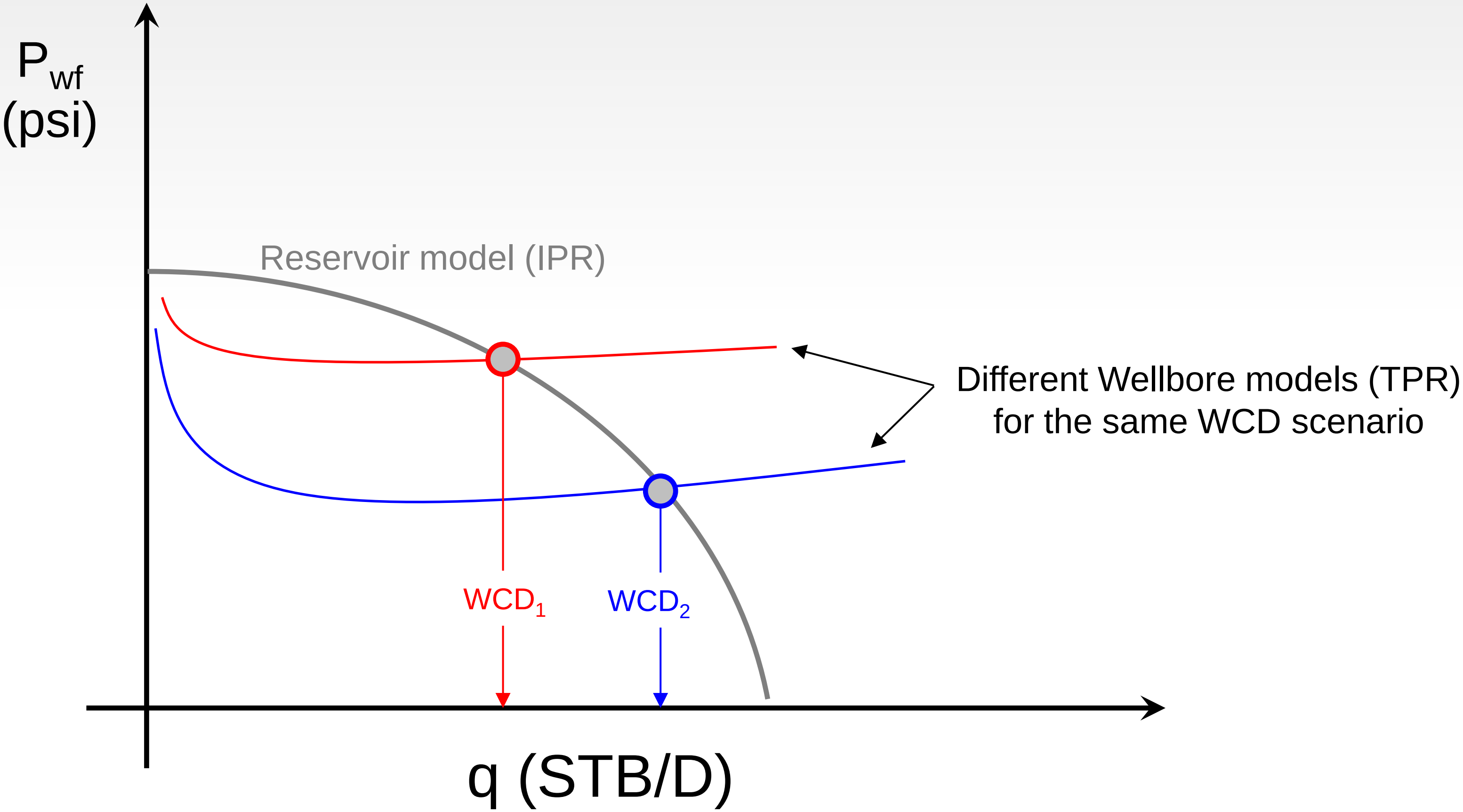
Perform quality assurance
- perform parametric sensitivity analysis (tornado diagram)
- WCD based on the best technical estimate for each parameter
- report a volume not a range

Report results

after SPE Technical Report (2015)

Statement of the Problem

- **WCD predictions** are directly dependent to flowing bottomhole pressure of the well:



Statement of the Problem

- ❑ ***q*** is calculated using reservoir and fluid properties, and $\boldsymbol{p_{wf}}$:

$$\boldsymbol{q} \propto \frac{kh(p_e - \boldsymbol{p_{wf}})}{B_o \mu \ln\left(\frac{r_e}{r_w}\right)}$$

(for $\boldsymbol{p_{wf} > p_{bp}}$)

reservoir and fluid prop.

- ❑ $\boldsymbol{p_{wf}}$ is obtained from wellbore flow correlations and wellhead conditions:

$$\boldsymbol{p_{wf}} = p_{wh} + \int_0^L \frac{\boldsymbol{dp}}{\boldsymbol{dL}} dL$$

generic pressure gradient equation

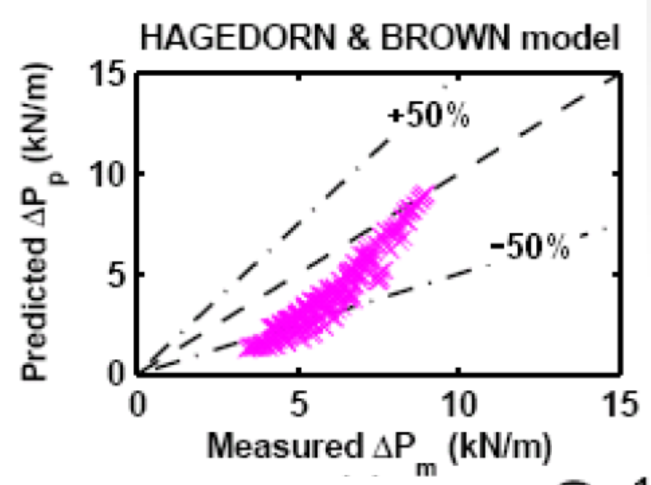
$$\frac{dp}{dz} = \frac{g}{g_c}\bar{\rho} + \frac{2f\bar{\rho}u_m^2}{g_c D} + \bar{\rho}\frac{\Delta(u_m^2/2g_c)}{\Delta z}$$

- Flow regimes
- Superficial velocities
- Pressure & temperature
- Fluid properties

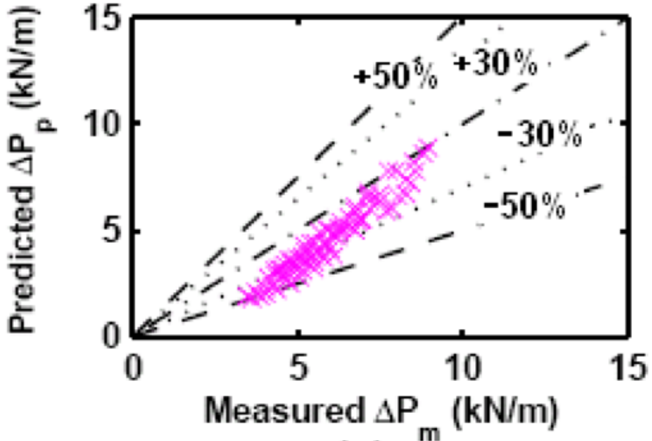
Statement of the Problem

- ☐ The use of flow correlations for **large diameter** pipes is **NOT well understood**:

Two-Phase flow in a vertical pipe (ID = 10 in)

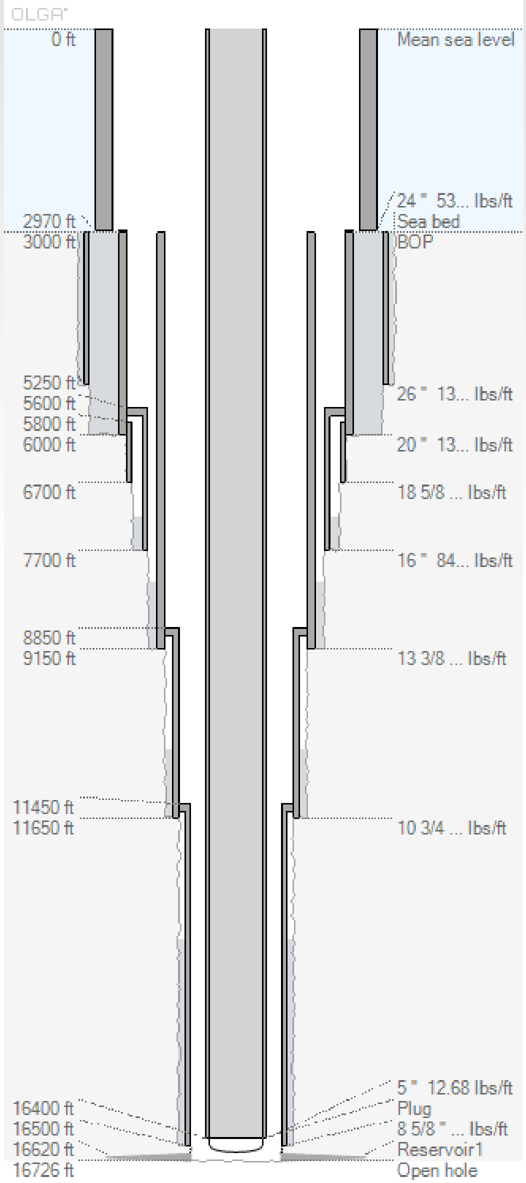


OLGA steady state model



Ali (2009)

Well configuration for typical WCD scenario



Main Objective of the Project

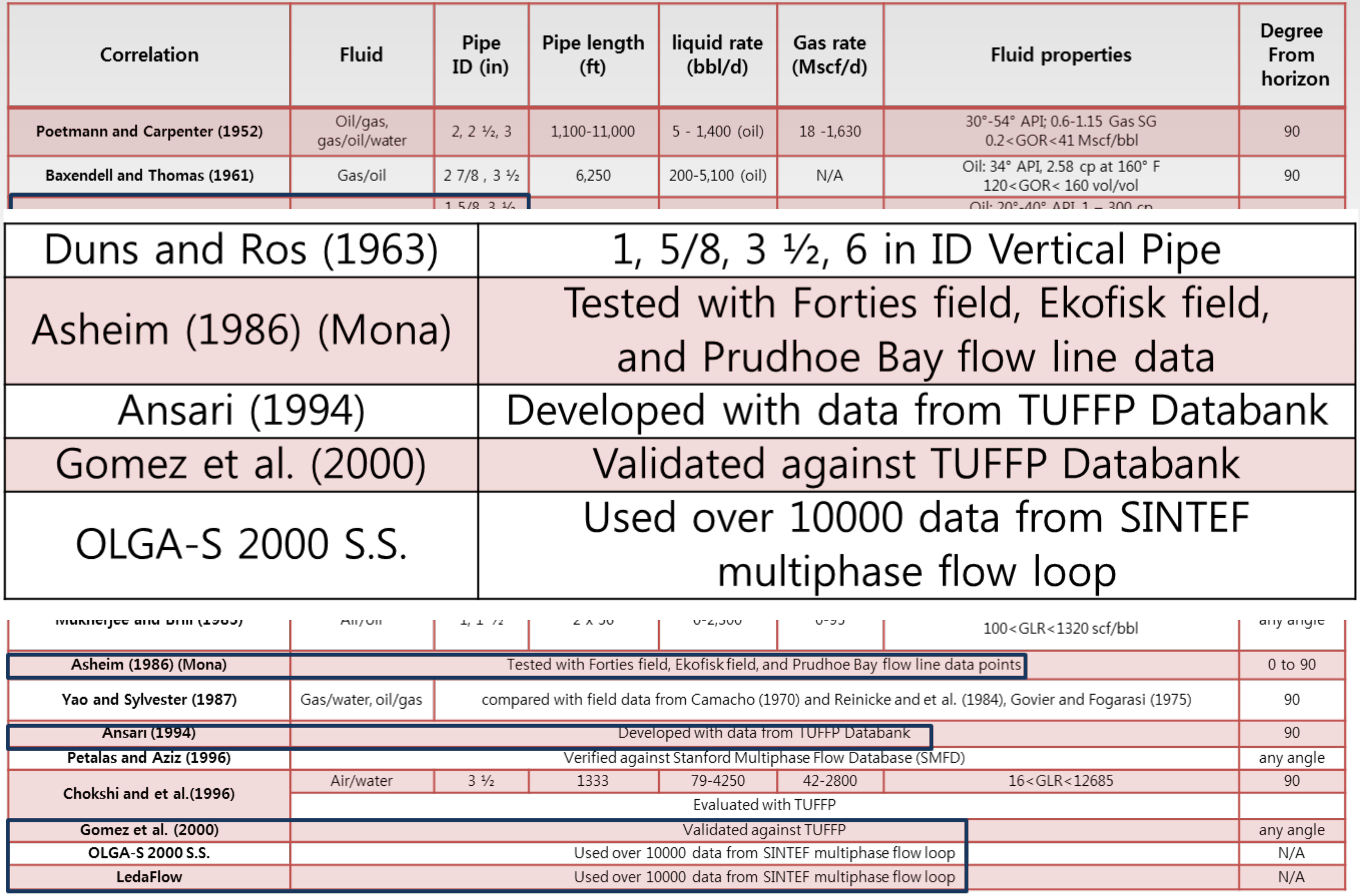
"The goal of this project is to **examine the validity of current industry standard flow correlations** used in WCD scenarios…"

Scope of Work/Deliverables:

- Task 1 - A complete literature review of flow correlations used in standard WCD software packages.
- Task 2 - A comparison between the different flow correlations for different base fluid properties at different "level" in a wellbore.
- Task 3&4 - Build experimental apparatus to investigate the effect of large pipe diameters (2, 4, 7, and 12 inches ID) on WCD analysis.
- Task 5&6 - Compare experimental data and simulation results to evaluate the performance of the correlations for large pipe diameter correlations.

Literature Review (Task 1)

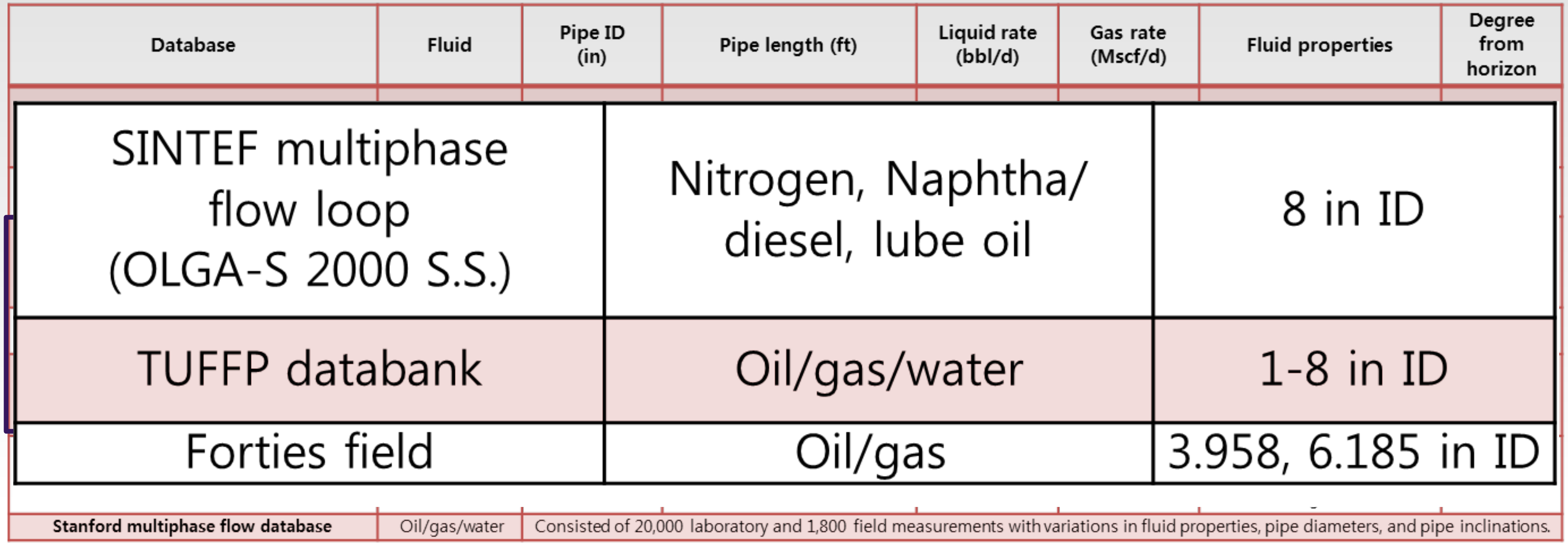
Review of Conditions Used to Develop Flow Models



Correlation	Fluid	Pipe ID (in)	Pipe length (ft)	liquid rate (bbl/d)	Gas rate (Mscf/d)	Fluid properties	Degree From horizon
Poetmann and Carpenter (1952)	Oil/gas, gas/oil/water	2, 2 ½, 3	1,100-11,000	5 - 1,400 (oil)	18 -1,630	30°-54° API; 0.6-1.15 Gas SG 0.2<GOR<41 Mscf/bbl	90
Baxendell and Thomas (1961)	Gas/oil	2 7/8 , 3 ½	6,250	200-5,100 (oil)	N/A	Oil: 34° API, 2.58 cp at 160° F 120<GOR< 160 vol/vol	90
		1 5/8, 3 ½				Oil: 20°-40° API 1 – 300 cp	
Mukherjee and Brill (1985)	Air/Oil	1, 1 ½	2 x 56	0-2,300	0-95	100<GLR<1320 scf/bbl	any angle
Asheim (1986) (Mona)	Tested with Forties field, Ekofisk field, and Prudhoe Bay flow line data points						0 to 90
Yao and Sylvester (1987)	Gas/water, oil/gas	compared with field data from Camacho (1970) and Reinicke and et al. (1984), Govier and Fogarasi (1975)					90
Ansari (1994)	Developed with data from TUFFP Databank						90
Petalas and Aziz (1996)	Verified against Stanford Multiphase Flow Database (SMFD)						any angle
Chokshi and et al.(1996)	Air/water	3 ½	1333	79-4250	42-2800	16<GLR<12685	90
	Evaluated with TUFFP						
Gomez et al. (2000)	Validated against TUFFP						any angle
OLGA-S 2000 S.S.	Used over 10000 data from SINTEF multiphase flow loop						N/A
LedaFlow	Used over 10000 data from SINTEF multiphase flow loop						N/A

Duns and Ros (1963)	1, 5/8, 3 ½, 6 in ID Vertical Pipe
Asheim (1986) (Mona)	Tested with Forties field, Ekofisk field, and Prudhoe Bay flow line data
Ansari (1994)	Developed with data from TUFFP Databank
Gomez et al. (2000)	Validated against TUFFP Databank
OLGA-S 2000 S.S.	Used over 10000 data from SINTEF multiphase flow loop

Review of Databases Used to Develop Flow Models



Database	Fluid	Pipe ID (in)	Pipe length (ft)	Liquid rate (bbl/d)	Gas rate (Mscf/d)	Fluid properties	Degree from horizon
SINTEF multiphase flow loop (OLGA-S 2000 S.S.)	Nitrogen, Naphtha/ diesel, lube oil	8 in ID					
TUFFP databank	Oil/gas/water	1-8 in ID					
Forties field	Oil/gas	3.958, 6.185 in ID					
Stanford multiphase flow database	Oil/gas/water	Consisted of 20,000 laboratory and 1,800 field measurements with variations in fluid properties, pipe diameters, and pipe inclinations.					

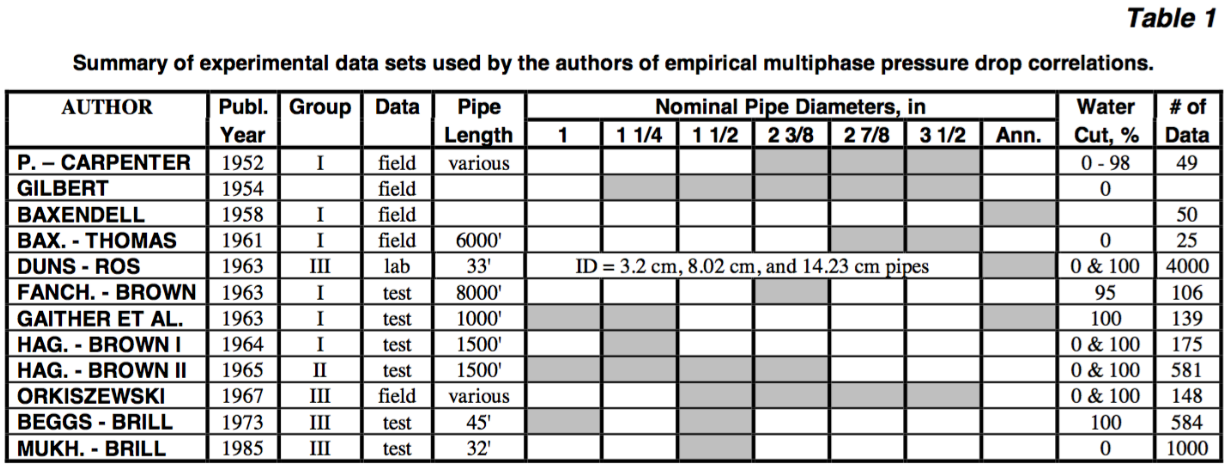


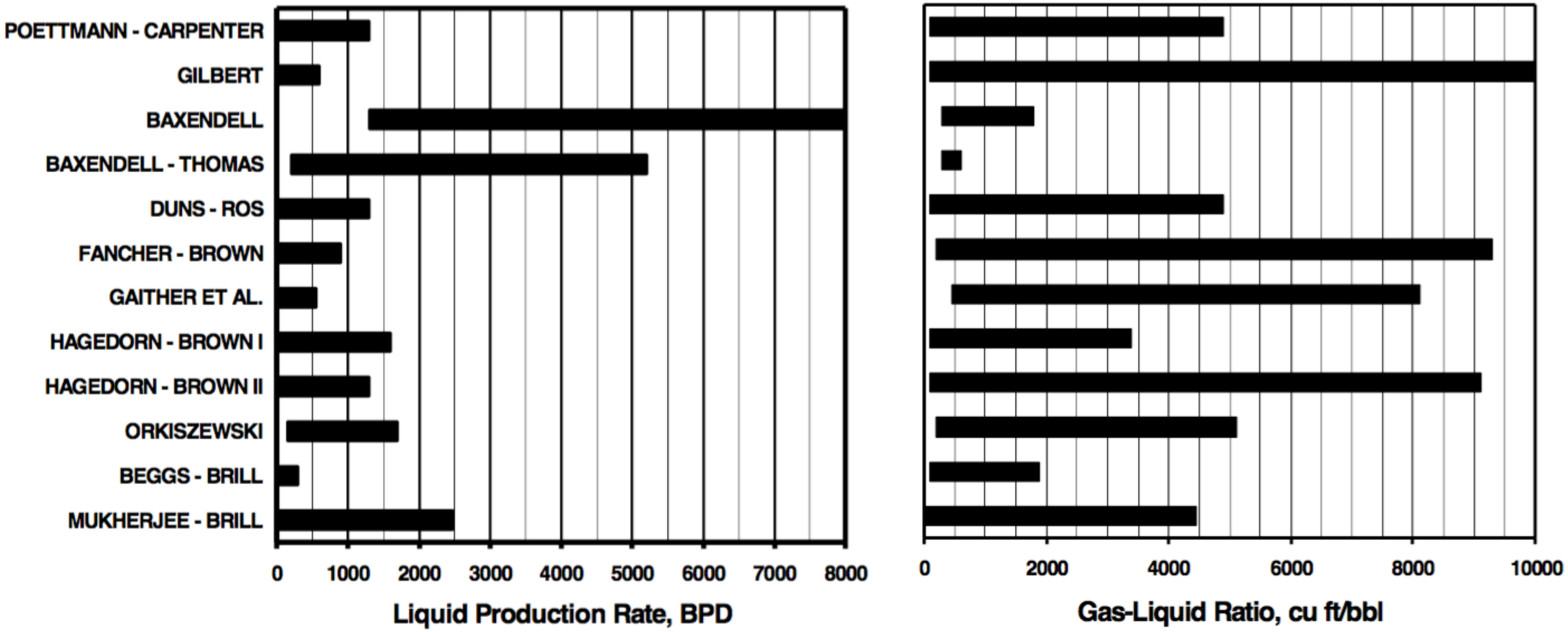
Table 1

Summary of experimental data sets used by the authors of empirical multiphase pressure drop correlations.

AUTHOR	Publ. Year	Group	Data	Pipe Length	Nominal Pipe Diameters, in							Water Cut, %	# of Data
					1	1 1/4	1 1/2	2 3/8	2 7/8	3 1/2	Ann.		
P. – CARPENTER	1952	I	field	various				▨	▨	▨		0 - 98	49
GILBERT	1954		field			▨	▨	▨	▨	▨		0	
BAXENDELL	1958	I	field								▨		50
BAX. - THOMAS	1961	I	field	6000'					▨	▨		0	25
DUNS - ROS	1963	III	lab	33'	ID = 3.2 cm, 8.02 cm, and 14.23 cm pipes						▨	0 & 100	4000
FANCH. - BROWN	1963	I	test	8000'				▨				95	106
GAITHER ET AL.	1963	I	test	1000'	▨	▨					▨	100	139
HAG. - BROWN I	1964	I	test	1500'		▨						0 & 100	175
HAG. - BROWN II	1965	II	test	1500'	▨	▨	▨	▨				0 & 100	581
ORKISZEWSKI	1967	III	field	various			▨	▨	▨	▨		0 & 100	148
BEGGS - BRILL	1973	III	test	45'	▨		▨					100	584
MUKH. - BRILL	1985	III	test	32'			▨					0	1000

Takacs (2001)

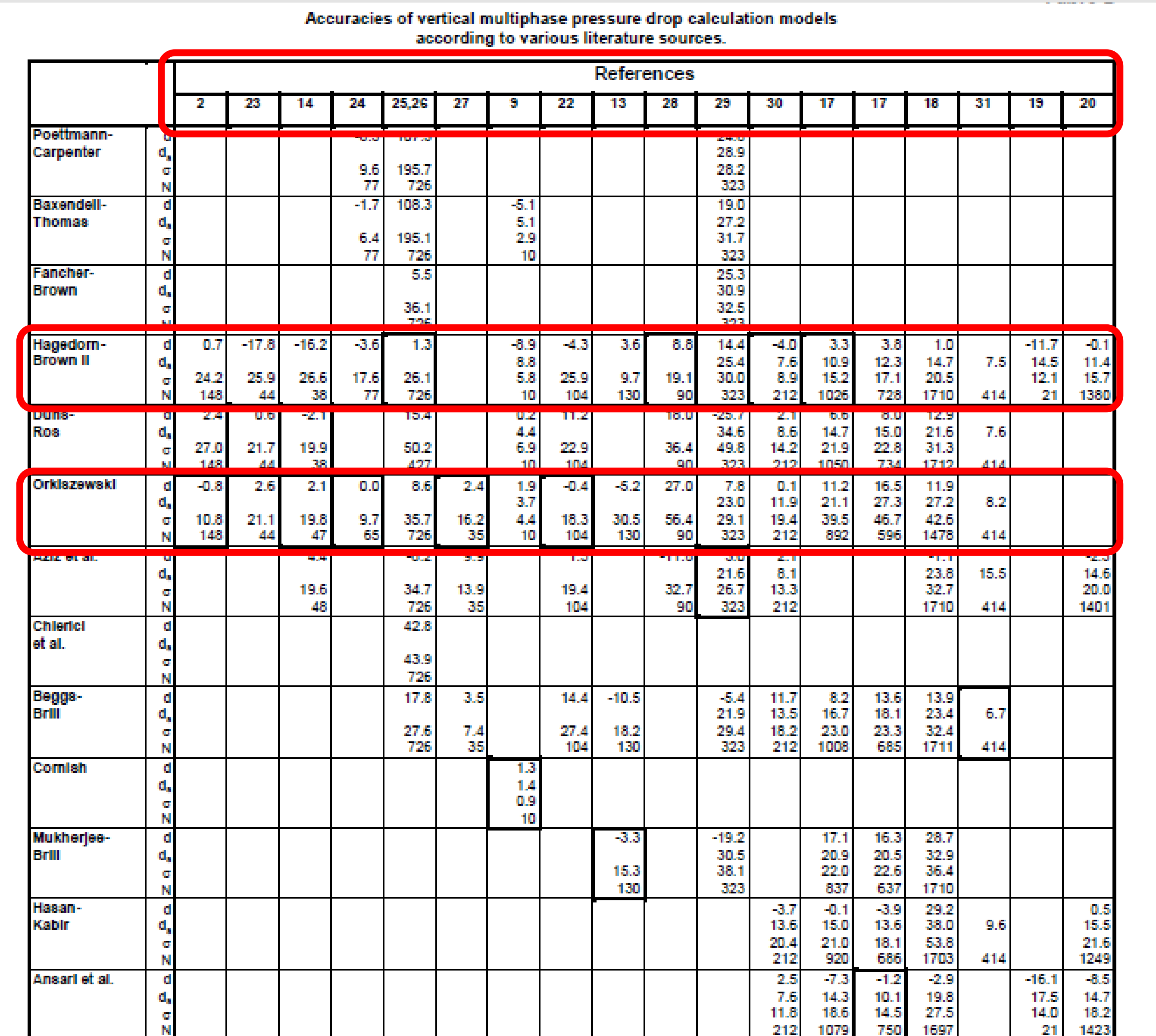
Review of Flow Rates Used to Develop Flow Models



Takacs (2001)

Review of Performance of Flow Models

Takacs (2001)

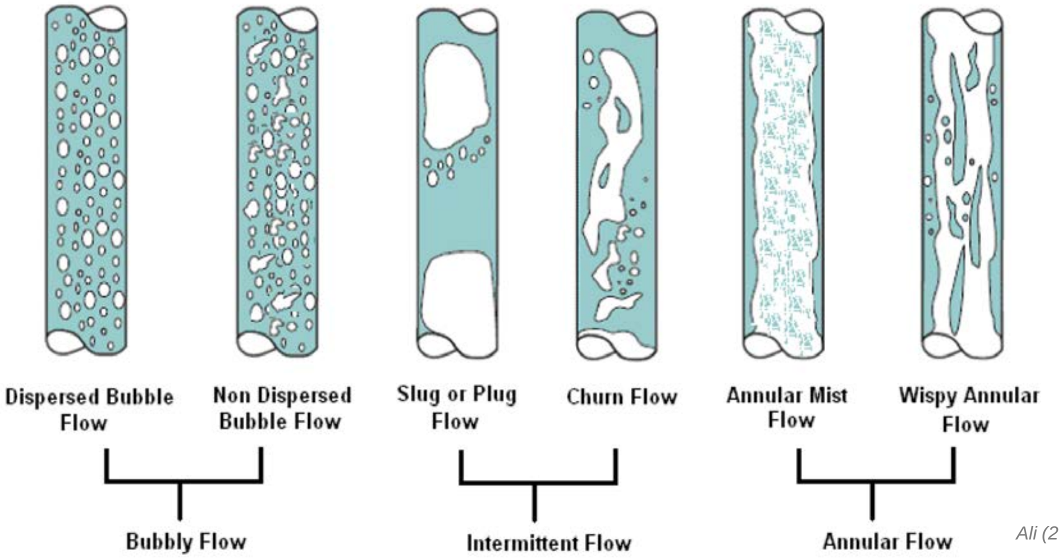


Accuracies of vertical multiphase pressure drop calculation models according to various literature sources.

		References																	
		2	23	14	24	25,26	27	9	22	13	28	29	30	17	17	18	31	19	20
Poettmann-Carpenter	d				[illegible]	[illegible]						[illegible]							
	d_s											28.9							
	σ				9.6	195.7						28.2							
	N				77	726						323							
Baxendell-Thomas	d				-1.7	108.3		-5.1				19.0							
	d_s							5.1				27.2							
	σ				6.4	195.1		2.9				31.7							
	N				77	726		10				323							
Fancher-Brown	d					5.5						25.3							
	d_s											30.9							
	σ					36.1						32.5							
	N					726						323							
Hagedorn-Brown II	d	0.7	-17.8	-16.2	-3.6	1.3		-8.9	-4.3	3.6	8.8	14.4	-4.0	3.3	3.8	1.0		-11.7	-0.1
	d_s							8.8				25.4	7.6	10.9	12.3	14.7	7.5	14.5	11.4
	σ	24.2	25.9	26.6	17.6	26.1		5.8	25.9	9.7	19.1	30.0	8.9	15.2	17.1	20.5		12.1	15.7
	N	148	44	38	77	726		10	104	130	90	323	212	1026	728	1710	414	21	1380
Duns-Ros	d	2.4	0.6	-2.1		15.4		0.2	11.2		18.0	-25.7	2.1	6.6	8.0	12.9			
	d_s							4.4				34.6	8.6	14.7	15.0	21.6	7.6		
	σ	27.0	21.7	19.9		50.2		6.9	22.9		36.4	49.8	14.2	21.9	22.8	31.3			
	N	148	44	38		427		10	104		90	323	212	1050	734	1712	414		
Orkiszewski	d	-0.8	2.6	2.1	0.0	8.6	2.4	1.9	-0.4	-5.2	27.0	7.8	0.1	11.2	16.5	11.9			
	d_s							3.7				23.0	11.9	21.1	27.3	27.2	8.2		
	σ	10.8	21.1	19.8	9.7	35.7	16.2	4.4	18.3	30.5	56.4	29.1	19.4	39.5	46.7	42.6			
	N	148	44	47	65	726	35	10	104	130	90	323	212	892	596	1478	414		
Aziz et al.	d			[illegible]		[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]			[illegible]			[illegible]
	d_s											21.6	8.1			23.8	15.5		14.6
	σ			19.6		34.7	13.9		19.4		32.7	26.7	13.3			32.7			20.0
	N			48		726	35		104		90	323	212			1710	414		1401
Chierici et al.	d					42.8													
	d_s																		
	σ					43.9													
	N					726													
Beggs-Brill	d					17.8	3.5		14.4	-10.5		-5.4	11.7	8.2	13.6	13.9			
	d_s											21.9	13.5	16.7	18.1	23.4	6.7		
	σ					27.6	7.4		27.4	18.2		29.4	18.2	23.0	23.3	32.4			
	N					726	35		104	130		323	212	1008	685	1711	414		
Cornish	d							1.3											
	d_s							1.4											
	σ							0.9											
	N							10											
Mukherjee-Brill	d									-3.3		-19.2		17.1	16.3	28.7			
	d_s											30.5		20.9	20.5	32.9			
	σ									15.3		38.1		22.0	22.6	36.4			
	N									130		323		837	637	1710			
Hasan-Kabir	d												-3.7	-0.1	-3.9	29.2			0.5
	d_s												13.6	15.0	13.6	38.0	9.6		15.5
	σ												20.4	21.0	18.1	53.8			21.6
	N												212	920	686	1703	414		1249
Ansari et al.	d												2.5	-7.3	-1.2	-2.9		-16.1	-8.5
	d_s												7.6	14.3	10.1	19.8		17.5	14.7
	σ												11.8	18.6	14.5	27.5		14.0	18.2
	N												212	1079	750	1697		21	1423

Why Flow Regime Predictions are Important for WCD calculations?

Correlations	Flow patterns
Duns and Ros (1963)	bubble, slug, and froth
Hagedorn and Brown (1964)	no flow pattern consideration
Hagedorn and Brown Modified (1965)	bubble, slug
Orkiszewski (1967)	bubble, slug, annular slug transition, annular mist
Beggs and Brill Revised (1973)	(horizontal pipe) segregated, intermitted, distributed, froth
Gray (1974)	no flow pattern consideration
Govier and Foragasi (1975)	slug, annular mist, froth
Mukherjee and Brill (1985)	no flow pattern consideration
Ansari (1994)	bubble, slug, and annular

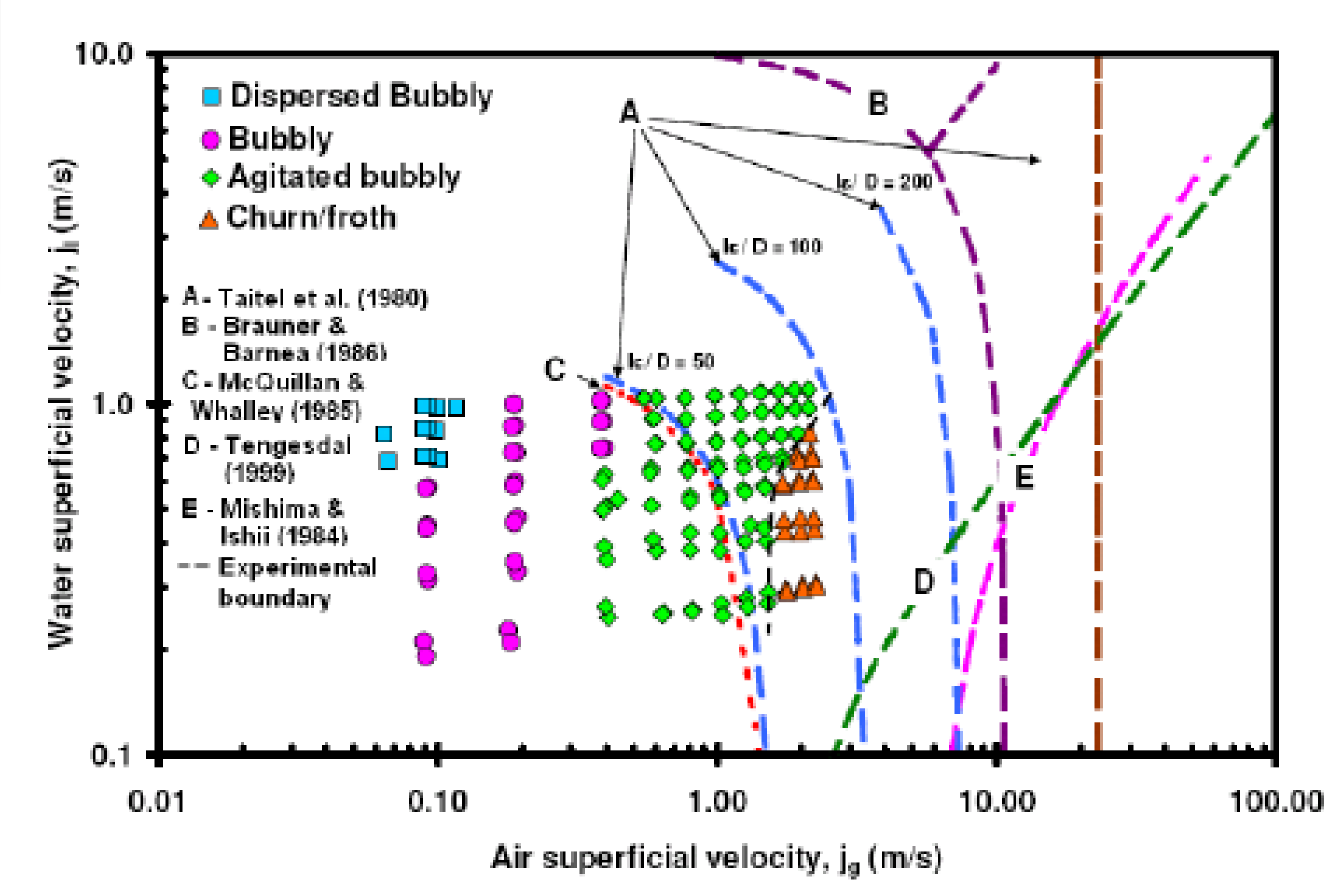


Ali (2009)

Flow Regime Maps for Large Diameter Pipe

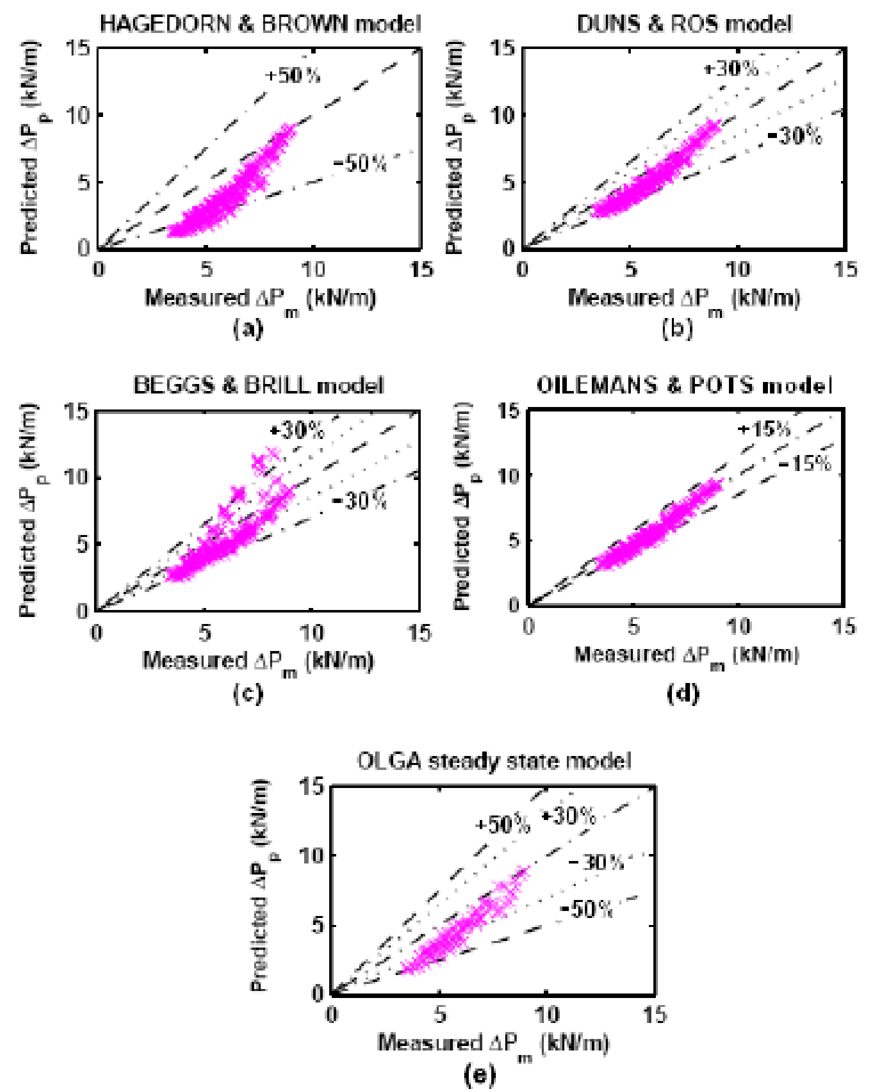
Ali (2009) - Experimental conditions tested

Study	Qo, BBL/D	Ql, GPM	ID, in	Ul, m/s	Rs, SCF/STB	Qg, MMSCF/D	Qg, SCFM	Ug, m/s
Ali	30,300	883	10	1.11	41	0.350	243	2.26



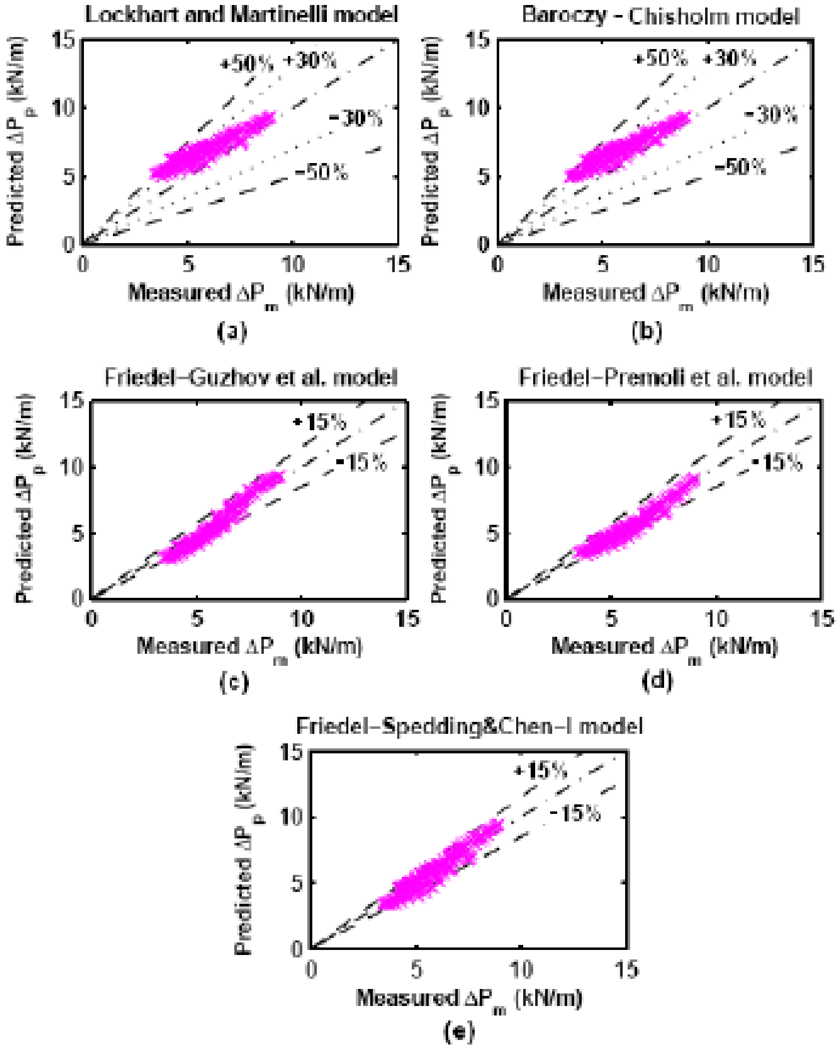
Evaluation of “Common” Flow Correlations

Ali (2009) – pipe ID = 10 in



Evaluation of Uncommon Flow Correlations

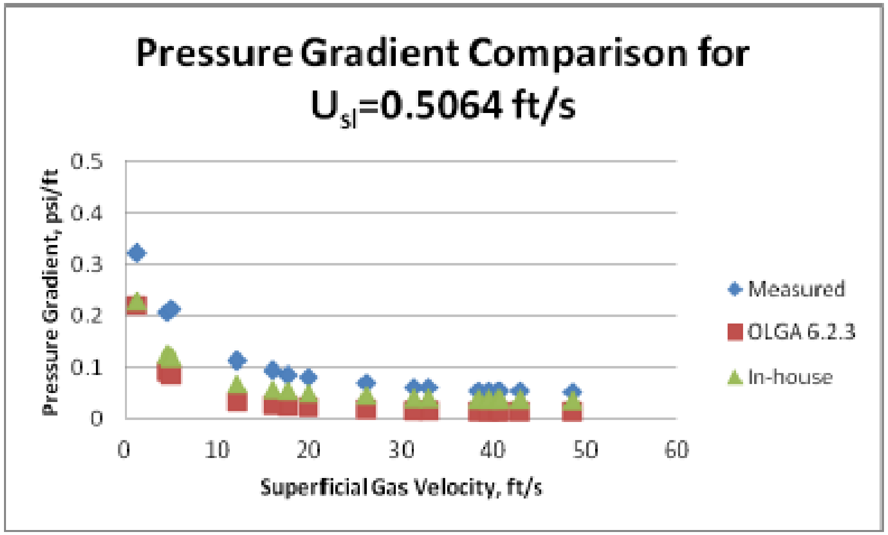
Ali (2009) – pipe ID = 10 in

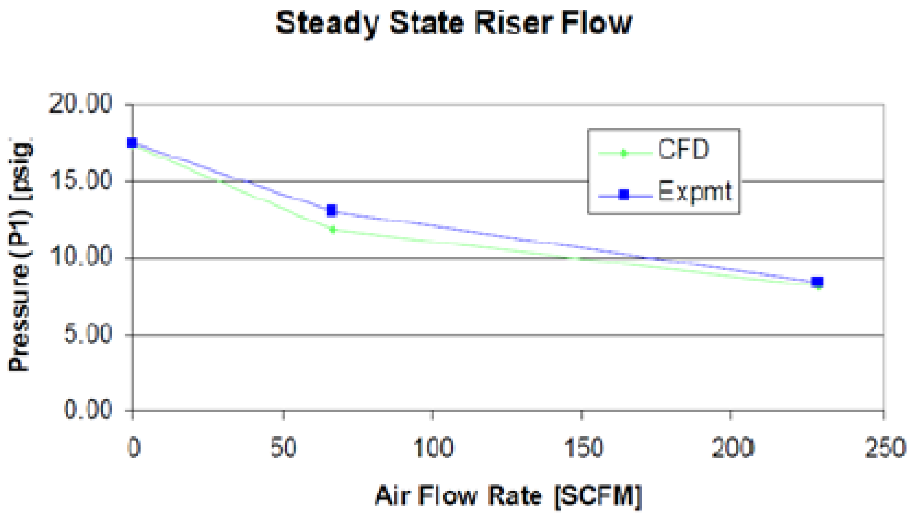


Evaluation of Using CFD models for Multiphase flow in Large Pipe Diameters

Zabaras (2013) - Experimental conditions tested

Study	Qo, BBL/D	Ql, GPM	ID, in	vsl, m/s	Rs, SCF/STB	Qg, MMSCF/D	Qg, SCFM	Ug, m/s
Zabaras	5140	150	11	0.15	2640	2.97	2063	15.9



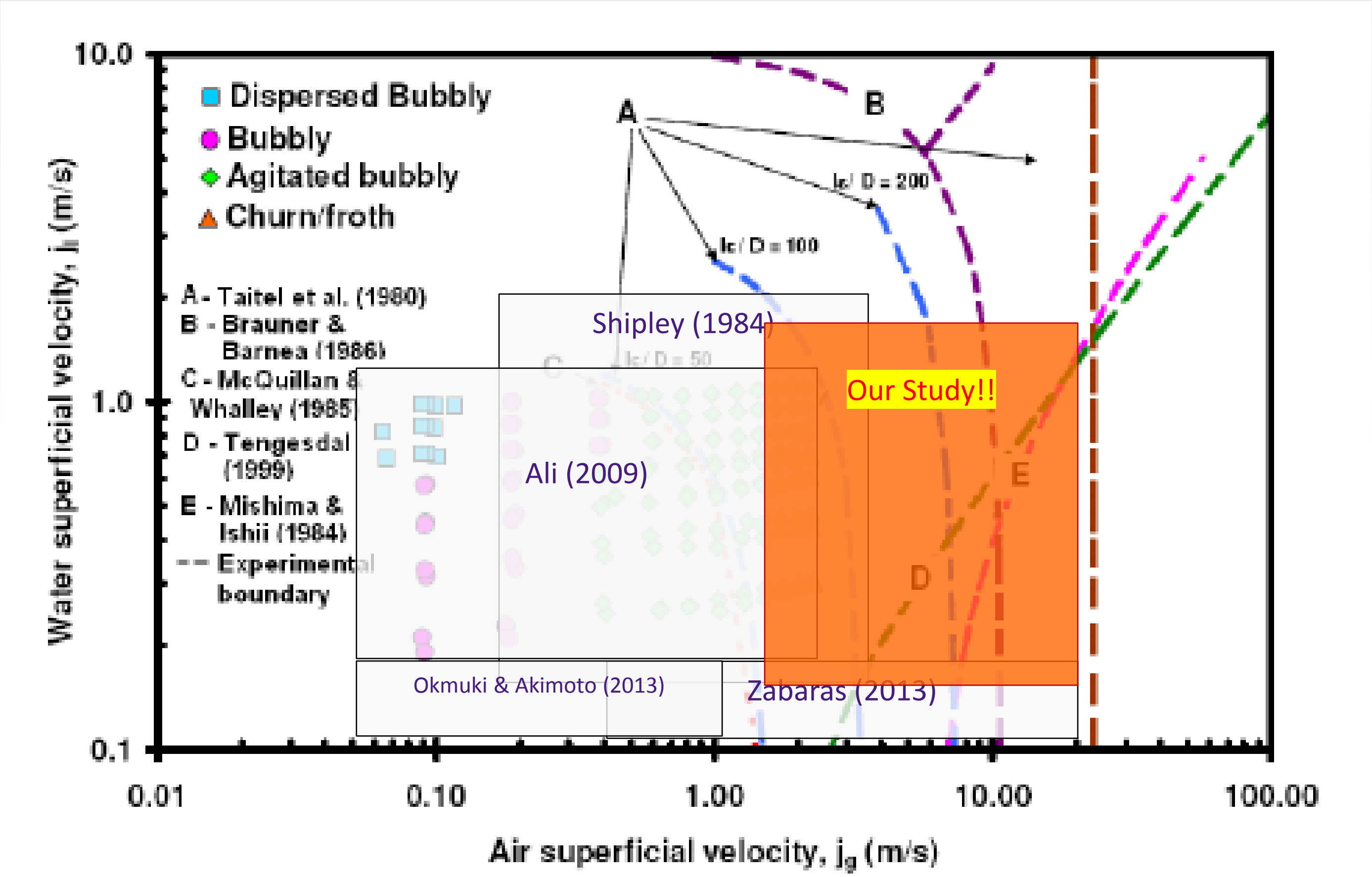


Gaps in Experimental Data for Large Pipe Diameters (ID > 10”)

modified after Ali (2009)

Researcher	Year	Fluid System	Diameter (mm)	L/D	$j_{g\,max}$ (m/s)	$j_{l\,max}$ (m/s)	Pressure (MPa)
Hills	1976	air-water	150	70	0.62 - 3.5	0.5 - 2.6	0.1
Shipley	1984	air-water	457	12.34	5	2	0.1
Clark and Flemmer	1986	air-water	100	10	-	-	0.1
Hashemi et al.	1986	air-water	305	9.41	1.16	0.06	0.1
Hirao et al.	1986	steam–water	120	-	1	4	0.5; 1.0 and 1.5
Ohnuki and Akimoto	1996	air-water	480	4.2	0.02 - 0.87	0.01 - 0.2	0.1
Cheng et al.	1998	air-water	150	70	1.113	1.25	0.1
Ohnuki and Akimoto	2000	air-water	200	61.5	0.03 - 4.7	0.06 - 1.06	0.1
Shoukri et al.	2000	air-water	100 & 200	43	0.02 - 15.5	0 - 1.8	0.1
Hibiki and Ishii	2002	nitrogen-water	102	53.9	0.286	0.387	0.1
Yoneda et al	2002	steam–water	155	23.9	0.25	0.6	0.2 to 0.5
Prasser et al.	2002	air-water	200	-	0.037 - 1.30	1	0.1
Sun et al.	2002	air-water	123	106.7	0.122	0.011 & 0.15	0.1
Hibiki and Ishii	2003	nitrogen-water	102	53.9	0.146	0.198	0.1
Oddie et al.	2003	nitrogen-water	150	73.33	1.57	1.57	-
Sun et al.	2003	air-water	102	40	0.502	0.058 - 1.03	0.1
Shen et al	2005	air–water	200	120	0.031- 0.372	0.035-1.06	0.1
Shen et al	2006	air–water	200	60.5	0.032 - 0.218	0.144 - 1.12	0.1
Omebere et al.	2007	nitrogen-naphtha	189	264.5	4.0	15.0	2.0 & 9.0
Ali	2009	air-water	254	46	4.44	3	0.1
Schlegel et al	2012	air-water	152 & 203	34 & 26	3	1	0.18 to 0.28
Smith et al	2012	air-water	102 & 152	30 & 18	10 to 20	4 to 10	0.5
Meulen	2012	air-water	127	86	3 to 20	0.004 – 0.7	0.3
Zabaras et al	2013	air-water	280	43.6	0.025 - 0.154	0.5663	0.69

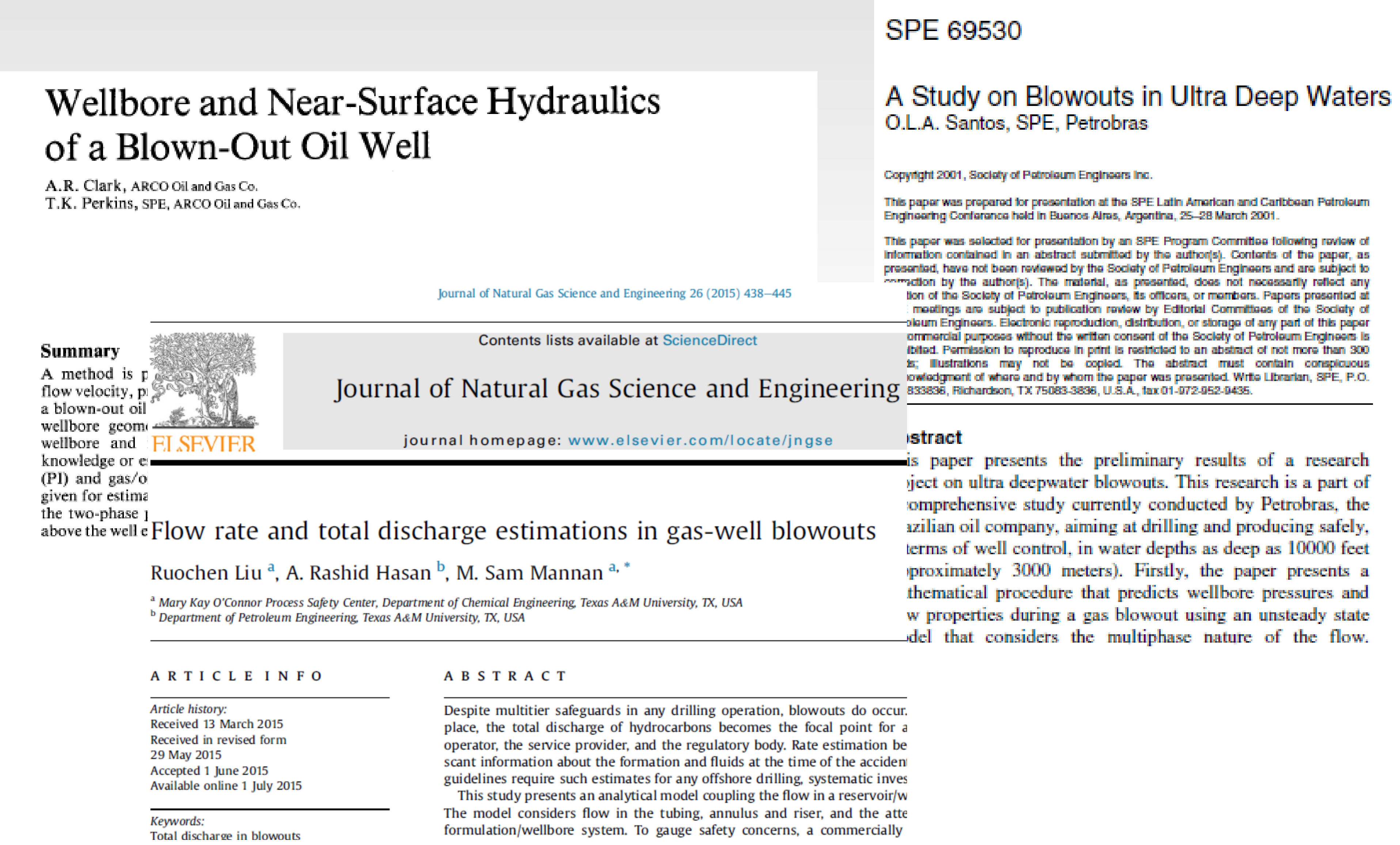
Gaps in Experimental for Large Pipe Diameters



Operational Enveloped for PERTT Lab Flow Loop

	Ali (2009)	**Zabaras et al. (2013)**	**LSU PERTT Lab**
Pipe length (ft)	40	40	100 (Max)
Pipe diameter (in)	10	11	12
Fluid	air, water	air, water	air, water
Max Liquid rate (BBL/D)	31,000	5,100	To be determined
Liquid velocity (m/s)	1.11	0.15	
Max Gas rate (MMSCF/D)	0.35	2.7	
Gas velocity (m/s)	2.21	16	
Max GLR (SCF/STB)	40	2600	
Comparison	BBO, HBR, DR, OLGA, OP	OLGA, In-House	ANS, BBO, BBR, DR, GAF, GRAYO, GRAYM, HBR, HBRDR, MB, NOSLIP, ORK, OLGA

Worst-Case-Discharge Vastly Under Studied



SPE 69530

A Study on Blowouts in Ultra Deep Waters

O.L.A. Santos, SPE, Petrobras

This paper was prepared for presentation at the SPE Latin American and Caribbean Petroleum Engineering Conference held in Buenos Aires, Argentina, 25–28 March 2001.

stract

is paper presents the preliminary results of a research
ject on ultra deepwater blowouts. This research is a part of
omprehensive study currently conducted by Petrobras, the
azilian oil company, aiming at drilling and producing safely,
terms of well control, in water depths as deep as 10000 feet
pproximately 3000 meters). Firstly, the paper presents a
thematical procedure that predicts wellbore pressures and
w properties during a gas blowout using an unsteady state
del that considers the multiphase nature of the flow.

Wellbore and Near-Surface Hydraulics of a Blown-Out Oil Well

A.R. Clark, ARCO Oil and Gas Co.
T.K. Perkins, SPE, ARCO Oil and Gas Co.

Summary

A method is p
flow velocity, p
a blown-out oil
wellbore geom
wellbore and
knowledge or e
(PI) and gas/o
given for estima
the two-phase p
above the well e

Journal of Natural Gas Science and Engineering 26 (2015) 438–445

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse

ELSEVIER

Flow rate and total discharge estimations in gas-well blowouts

Ruochen Liu [a], A. Rashid Hasan [b], M. Sam Mannan [a, *]

[a] Mary Kay O'Connor Process Safety Center, Department of Chemical Engineering, Texas A&M University, TX, USA
[b] Department of Petroleum Engineering, Texas A&M University, TX, USA

ARTICLE INFO

Article history:
Received 13 March 2015
Received in revised form
29 May 2015
Accepted 1 June 2015
Available online 1 July 2015

Keywords:
Total discharge in blowouts

ABSTRACT

Despite multitier safeguards in any drilling operation, blowouts do occur.
place, the total discharge of hydrocarbons becomes the focal point for a
operator, the service provider, and the regulatory body. Rate estimation be
scant information about the formation and fluids at the time of the acciden
guidelines require such estimates for any offshore drilling, systematic inves
This study presents an analytical model coupling the flow in a reservoir/w
The model considers flow in the tubing, annulus and riser, and the atte
formulation/wellbore system. To gauge safety concerns, a commercially

Conclusions from Literature Review

- ☐ Flow correlations were originally developed and still only verified for small pipe dimeters (ID < 8 inches)
- ☐ Experimental setup needs to preferably achieve high liquid and gas flow rates (Q_l > 30,000 bbl/d and Q_g > 1 MMSCF/D)
- ☐ Unpopular flow correlations should be evaluated to be used in WCD models
- ☐ Recent developments show CFD tool as a potential solution to generate simulations results to compete with one-dimensional flow correlations for large pipe diameters
- ☐ WCD models vastly under studied

Initial WCD Models Comparison (Task 2)

Description of Base Cases for Comparison Study

Dr. Muhammad Zulqarnain

CFD Model Description

Dr. Mayank Tyagi

Methodology for Comparison of Wellbore Flow Models

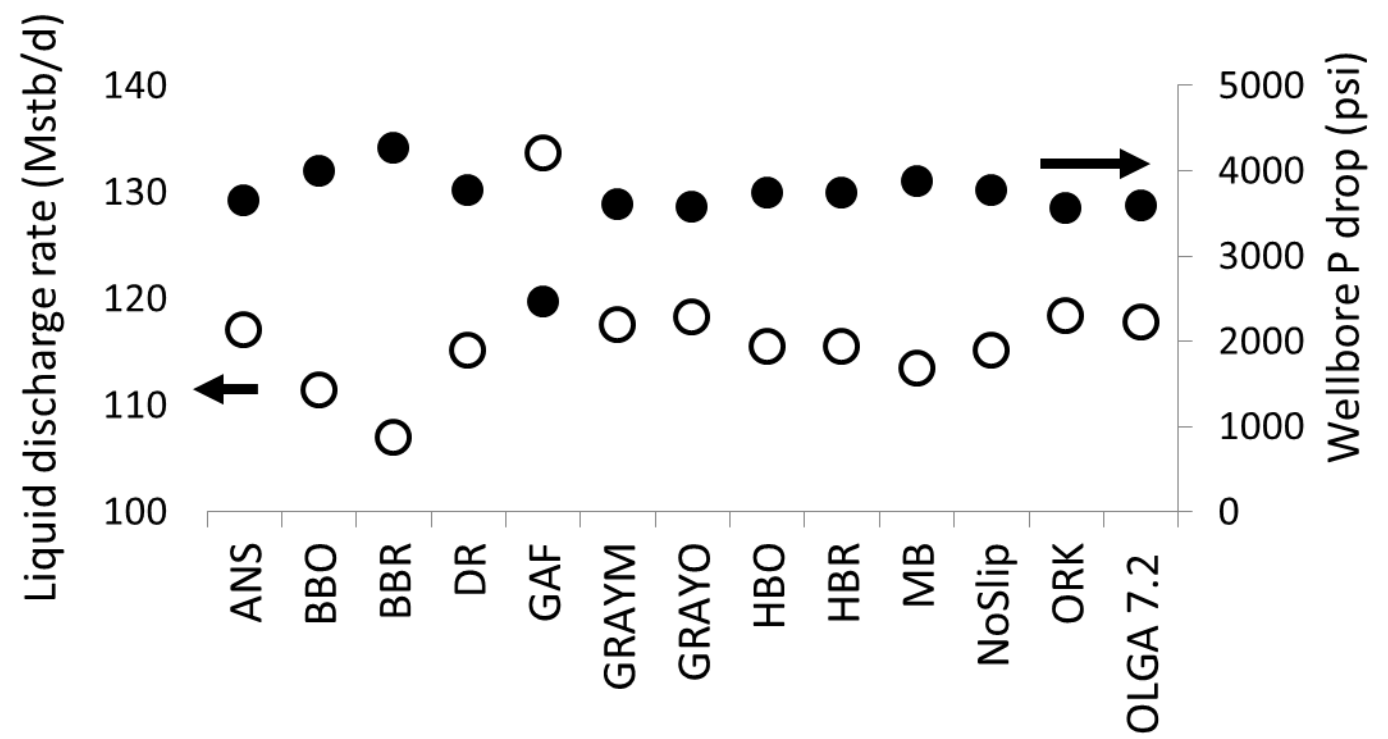
One-dimensional models

Wellbore flow model	Abbreviation
Ansari (1994)	ANS
Beggs and Brill (1973)	BBO
Beggs and Brill Revised	BBR
Duns and Ross (1963)	DR
Govier, Aziz, and Fogarasi (1972)	GAF
Gray Original (1974)	GRAYO
Gray modified	GRAYM
Hagedorn and Brown (1964)	HBR
Hagedorn and Brown with Duns and Ross map	HBRDR
Mukherjee and Brill (1985)	MB
No Slip	NOSLIP
Orkiszewski (1967)	ORK
OLGA 7.2	OLGA

- Common models available in commercial packages
- Models available in PIPESIM at LSU
- Include different model approaches (empirical, mechanistic, …)

Results for WCD Calculations for Different Wellbore Flow Models

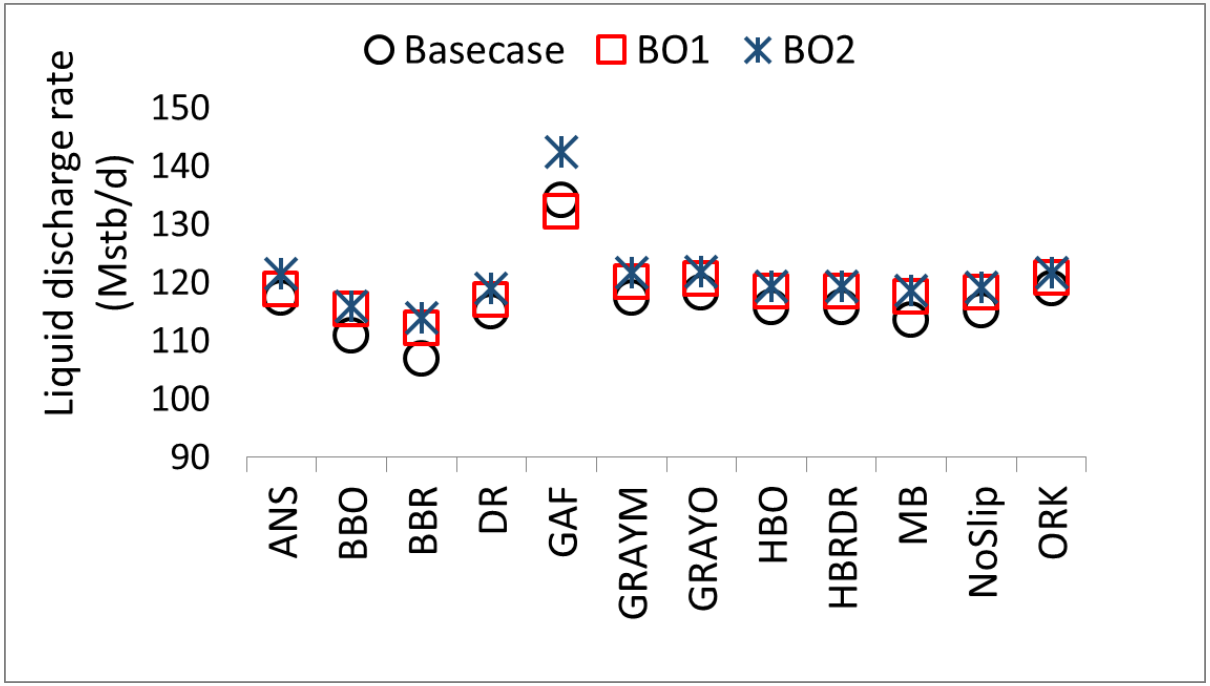
Base Case WCD calculation



Effect of Reservoir Fluid Properties

Black Oil Reservoir

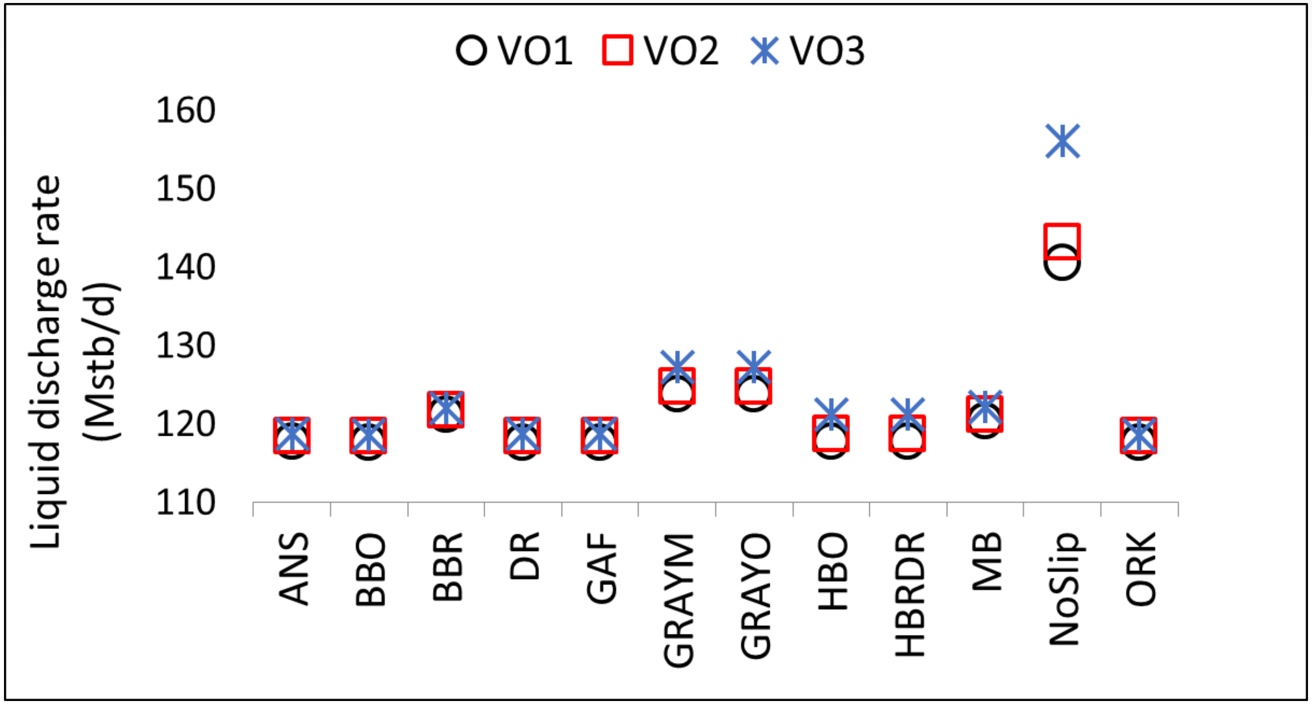
Base fluid	Reservoir measured depth (ft)	Reservoir pressure (psi)	Reservoir Temperature (°F)	GOR (scf/stb)	Bubble point Pressure (psi)	Oil gravity (API)	Oil viscosity (cp)
Basecase	16726	11305	210	1700	6306	28	0.8
BO1	19426	10391	166	1340	7693	25.3	1.49
BO2	19553	12523	251	1721	5192	34.5	0.12



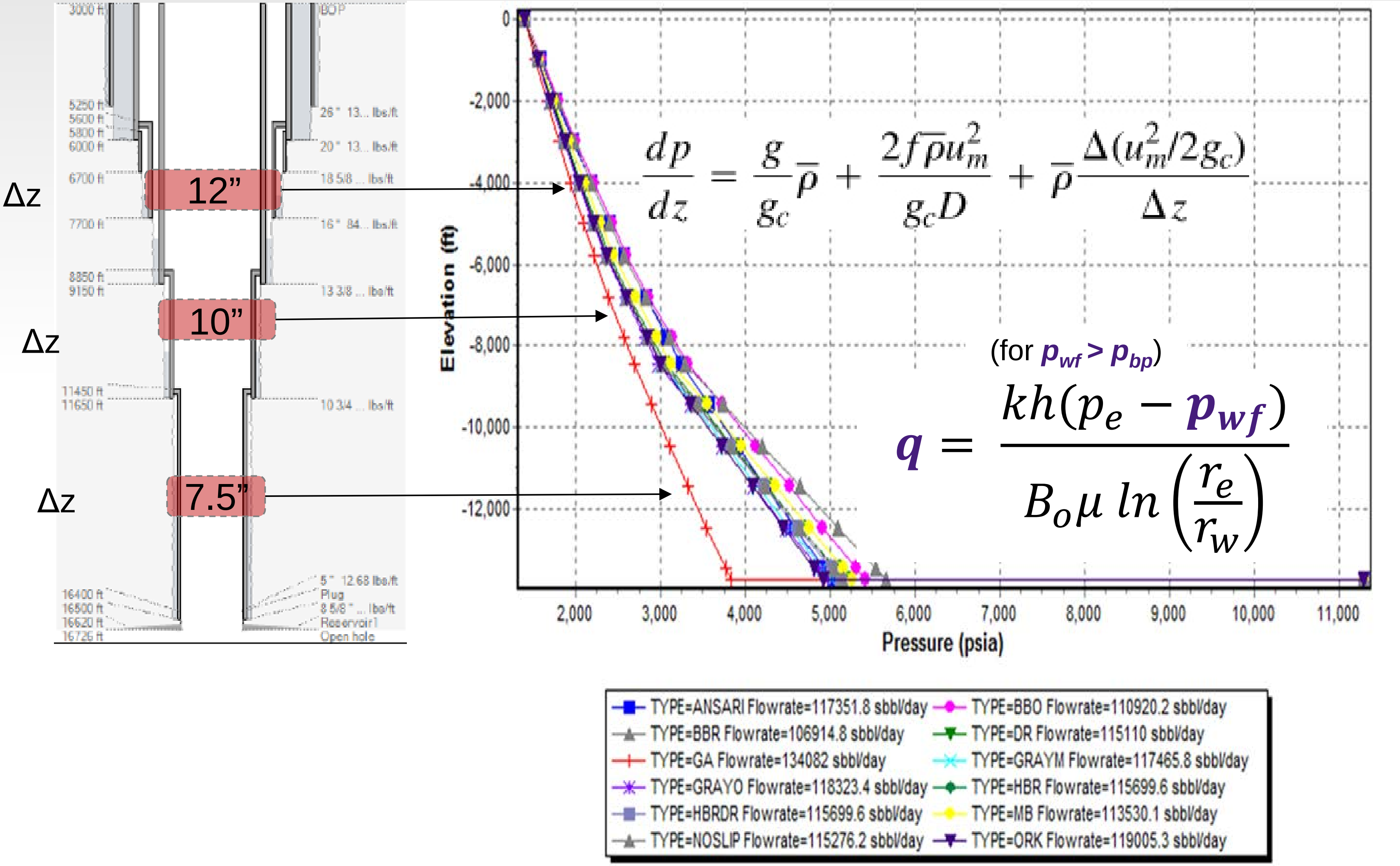
Effect of Reservoir Fluid Properties

Volatile Oil Reservoir

Base fluid	Reservoir measured depth (ft)	Reservoir pressure (psi)	Reservoir Temperature (°F)	GOR (scf/stb)
VO1	14631	11499	264	2123
VO2	14532	11055	263	1834
VO3	14374	11009	261	3451



Methodology for the Verification of Validity of Flow Models



$$\frac{dp}{dz} = \frac{g}{g_c}\bar{\rho} + \frac{2f\bar{\rho}u_m^2}{g_c D} + \bar{\rho}\frac{\Delta(u_m^2/2g_c)}{\Delta z}$$

(for $p_{wf} > p_{bp}$)

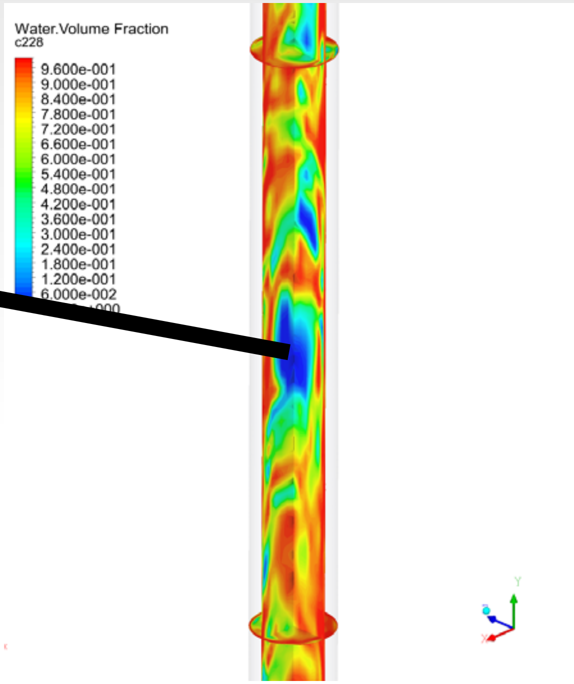
$$q = \frac{kh(p_e - p_{wf})}{B_o \mu \ln\left(\frac{r_e}{r_w}\right)}$$

Methodology on the Verification of Validity of Flow Models

Laboratorial data

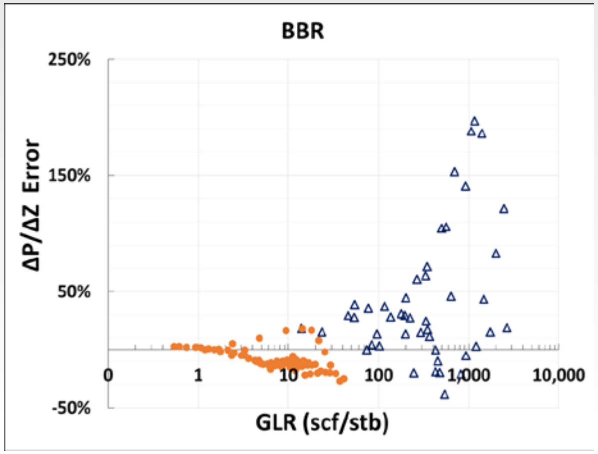
$$\frac{dp}{dz}$$

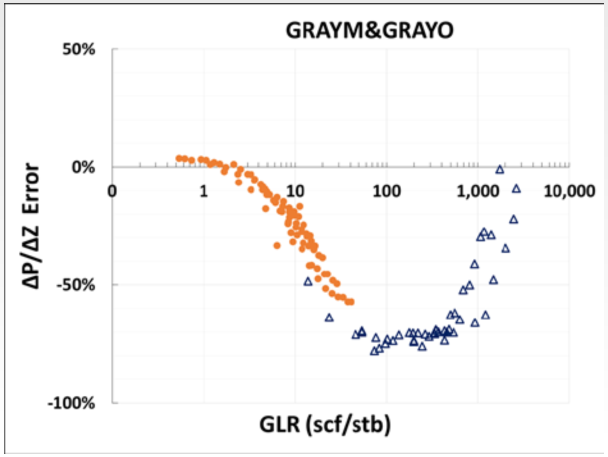
CFD model results

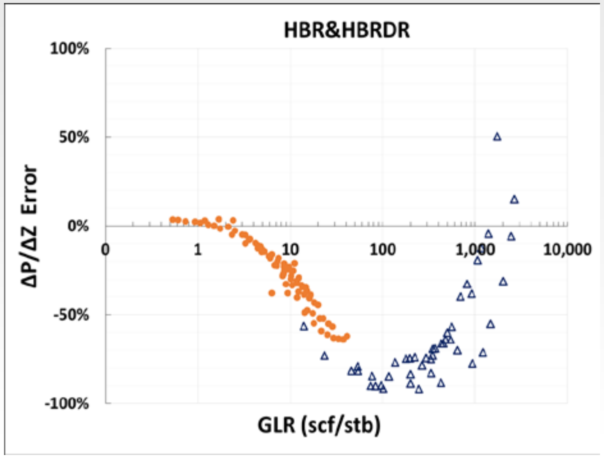


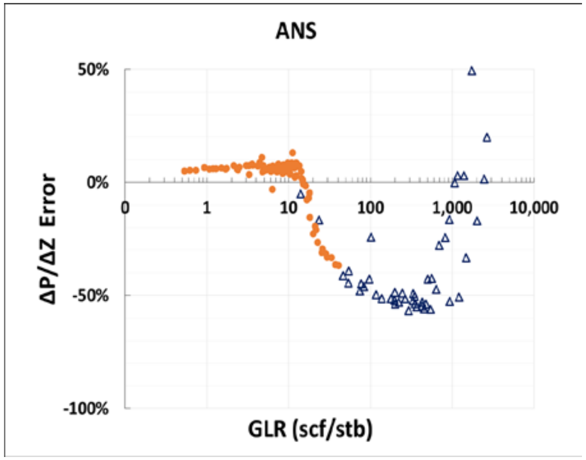
- Validity of using water and air rather than hydrocarbon liquid and gas:
  - ✓ Understand **hydraulics** issue and **PVT** issue **separately**!
  - ✓ A perfect **PVT model is useless** if the **hydraulic model is wrong**!

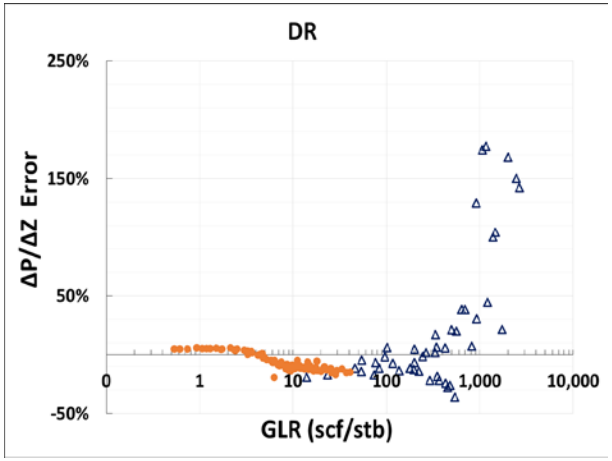
Results for Wellbore Flow model Verification with Laboratorial Data

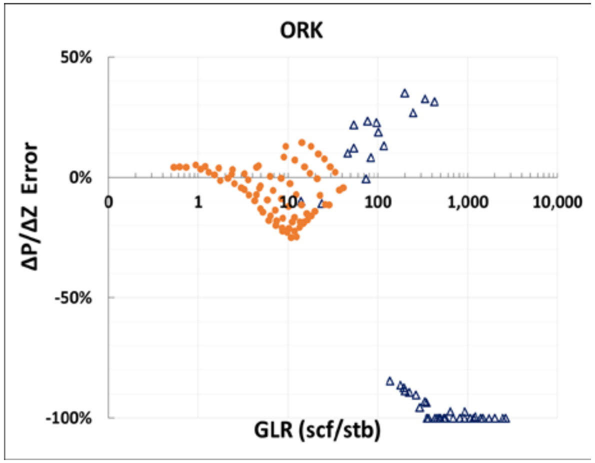

BBR


GRAYM&GRAYO

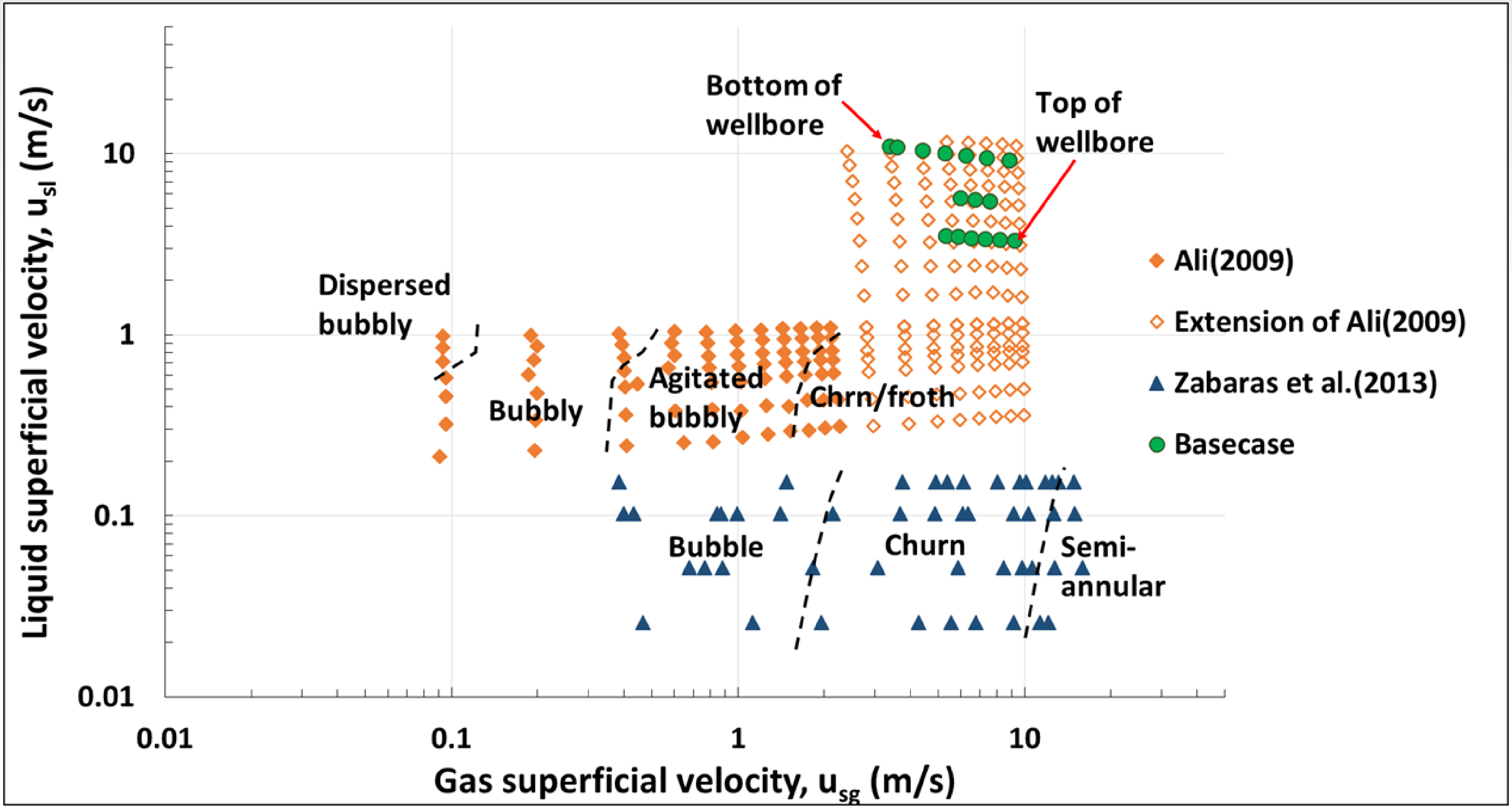

HBR&HBRDR


ANS

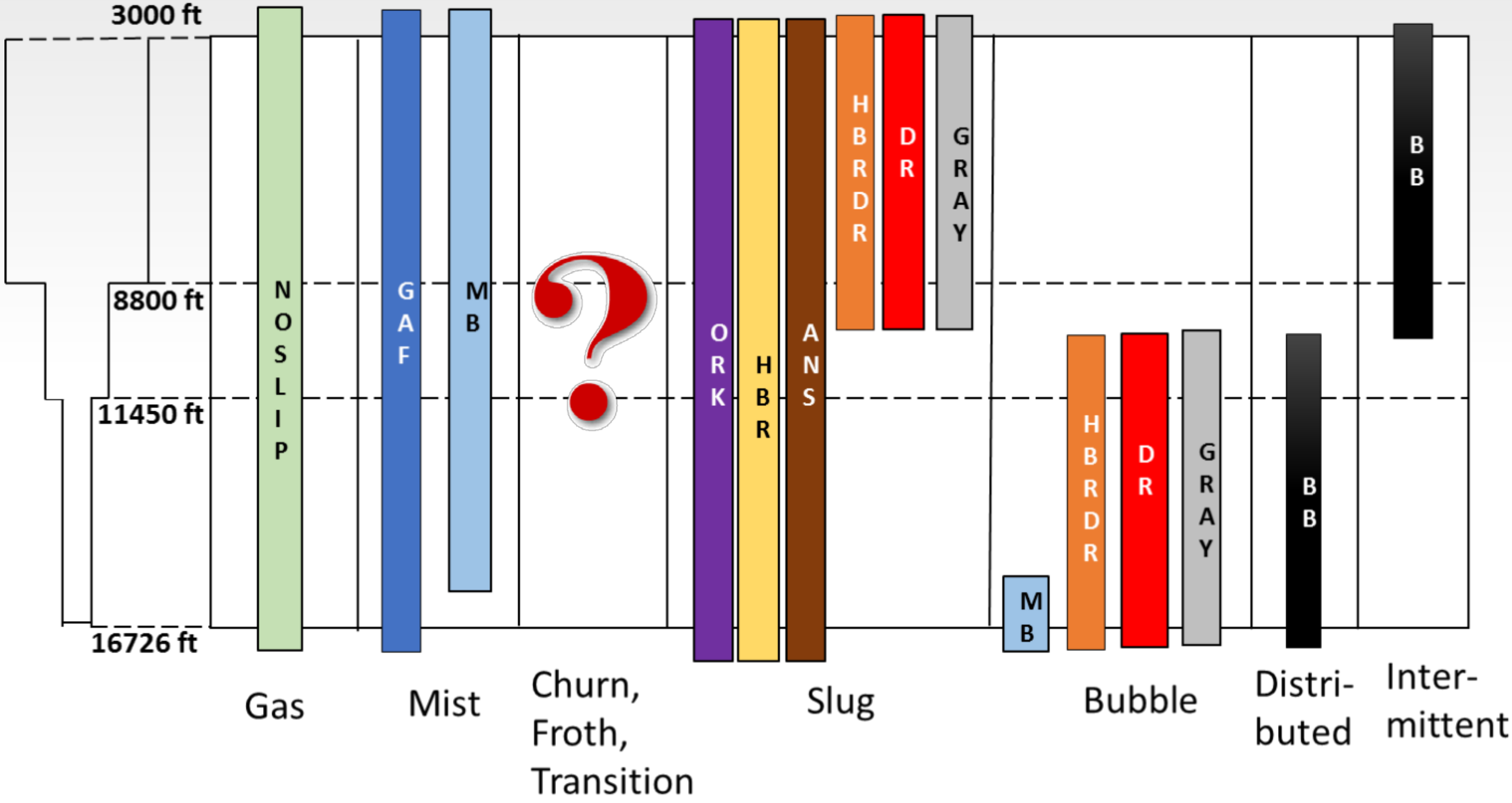

DR


ORK

Results for Flow Regime Prediction for Base Case

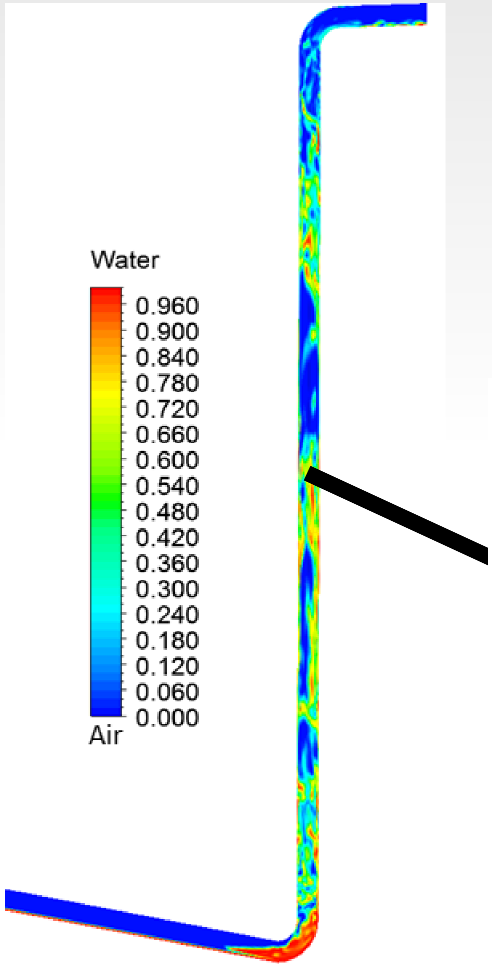


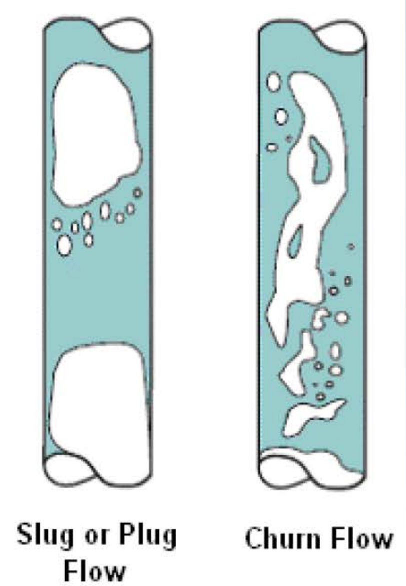
Results for Flow Regime Prediction for Base Case

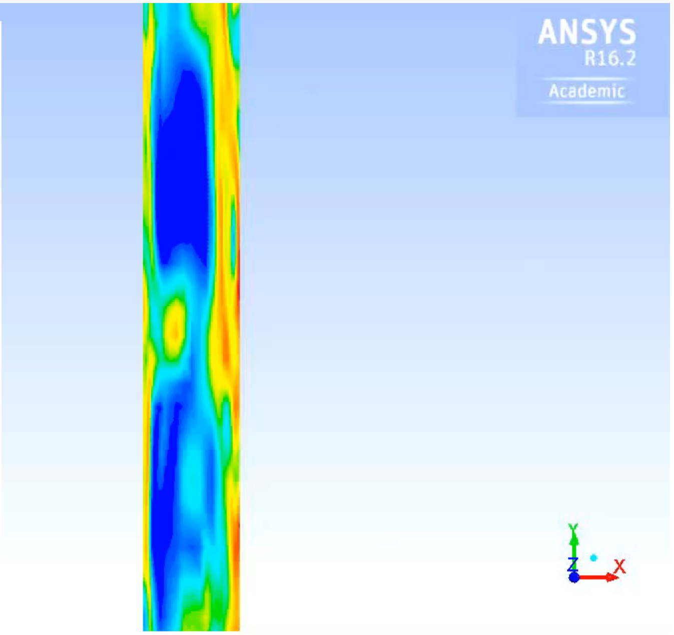


Results for CFD Validation for Large Diameter

Experimental Data Set	Pipe Dia (inches)	QL (STBD)	Qg (MM SCFD)	Exp. dp/dx (psi/ft)	CFD dp/dx (psi/ft)	Grid Points (K)	% deviation to Experimental pressure gradient
Zabaras et al. (2013)	11	5143	0.276	0.21	0.19	355	-7.1
		5143	2.786	0.051	0.04	355	-13.1
Ali (2009)	10	29804	0.221	0.26	0.32	382	~~22.1~~
		29804	0.221	0.26	0.29	610	11.1





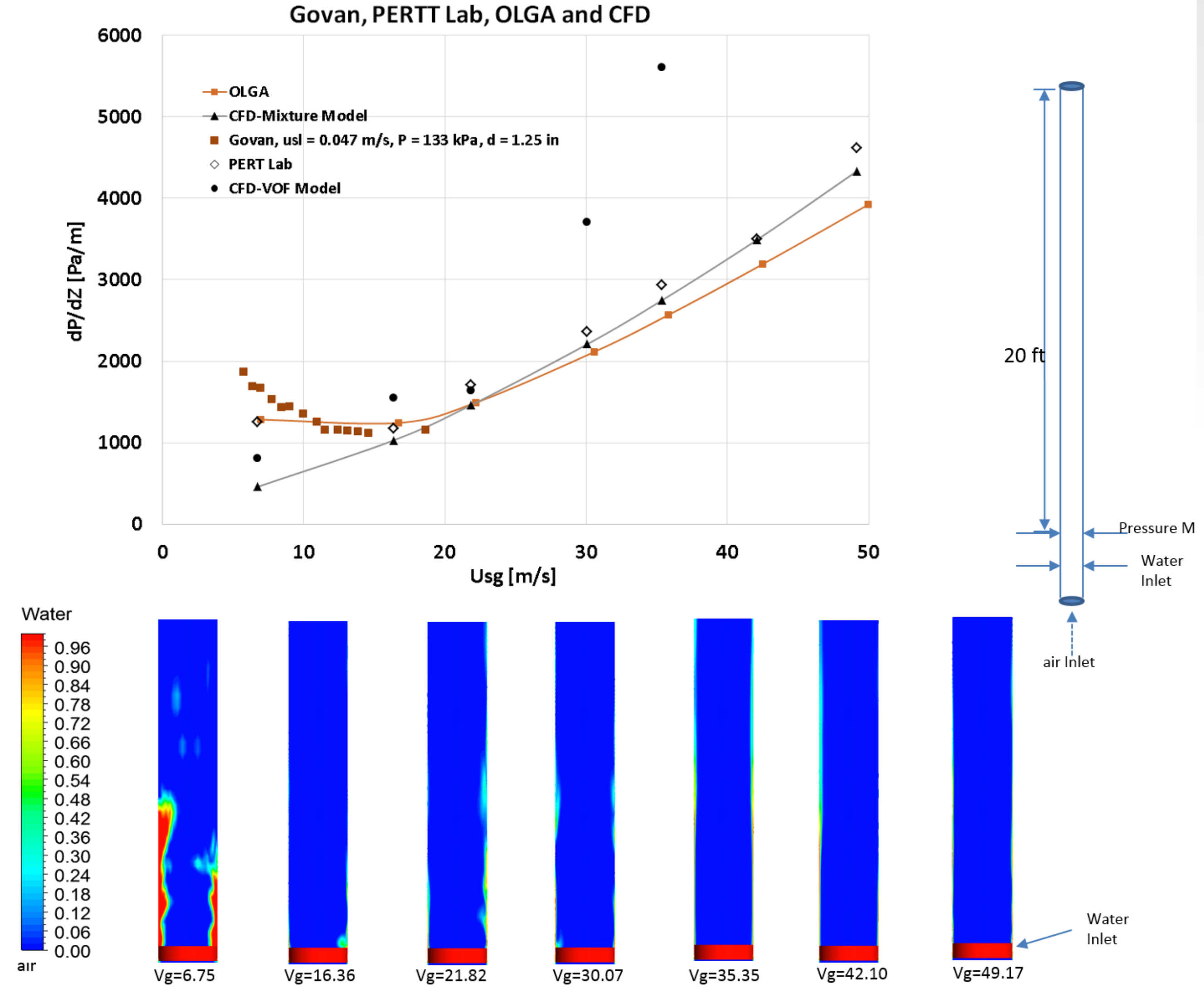


Contours of Volume fraction (water) (Time=4.2728e+01)

Jan 25, 2016

ANSYS Fluent Release 16.2 (3d, dp, pbns, vof, rngke, transient)

Results for CFD Validation for Small Diameter

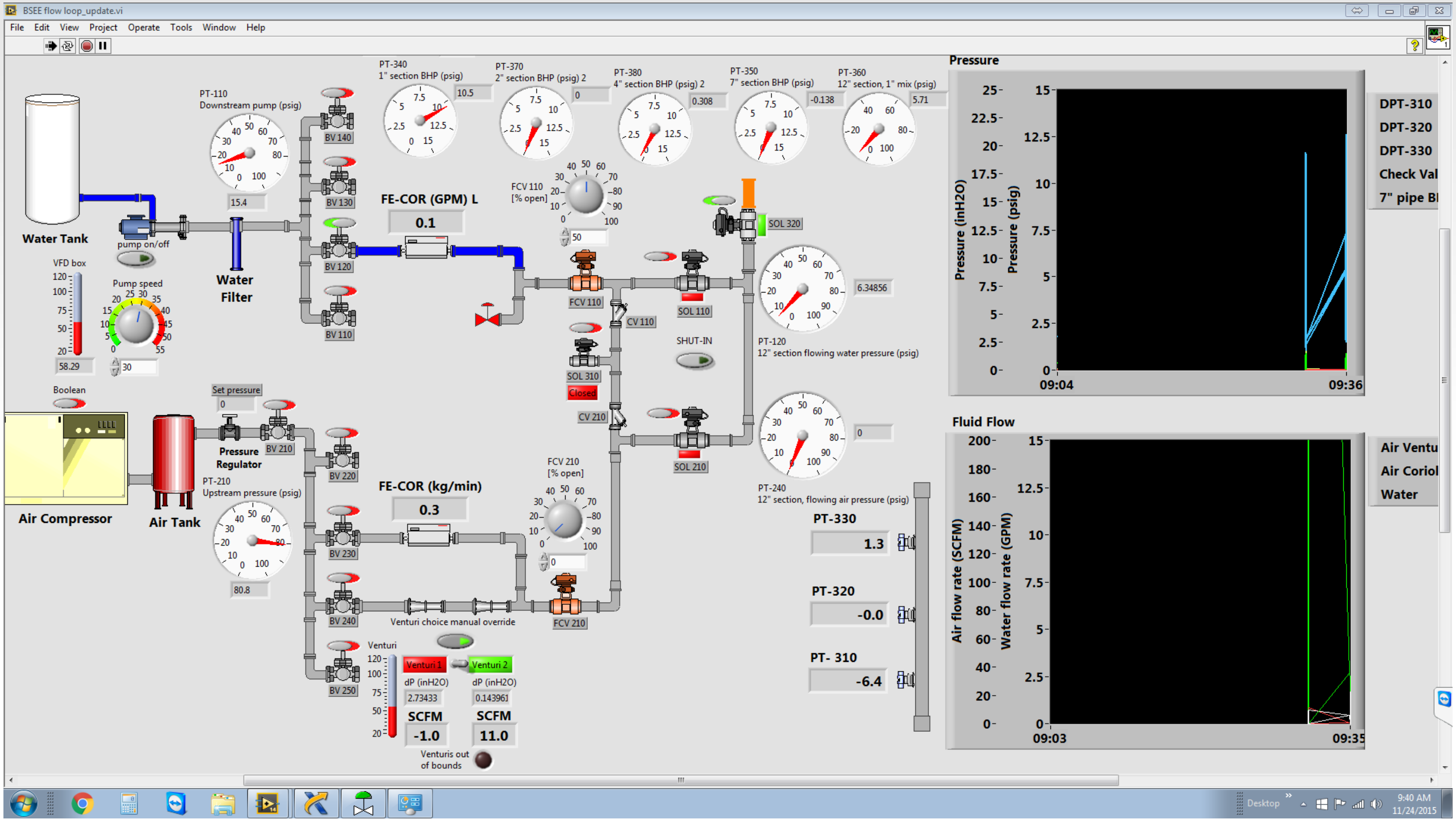


Progress on Experimental Work

Small and Intermediate Pipe IDs

Base Structure and Visualization for 12” ID

Monitoring and Control System



PT-340 1" section BHP (psig): 10.5

PT-370 2" section BHP (psig) 2: 0

PT-380 4" section BHP (psig) 2: 0.308

PT-350 7" section BHP (psig): -0.138

PT-360 12" section, 1" mix (psig): 5.71

PT-110 Downstream pump (psig): 15.4

FE-COR (GPM) L: 0.1

FCV 110 [% open]: 50

VFD box: 58.29

Pump speed: 30

SOL 310: Closed

PT-120 12" section flowing water pressure (psig): 6.34856

PT-240 12" section, flowing air pressure (psig): 0

Set pressure: 0

PT-210 Upstream pressure (psig): 80.8

FE-COR (kg/min): 0.3

FCV 210 [% open]: 0

PT-330: 1.3

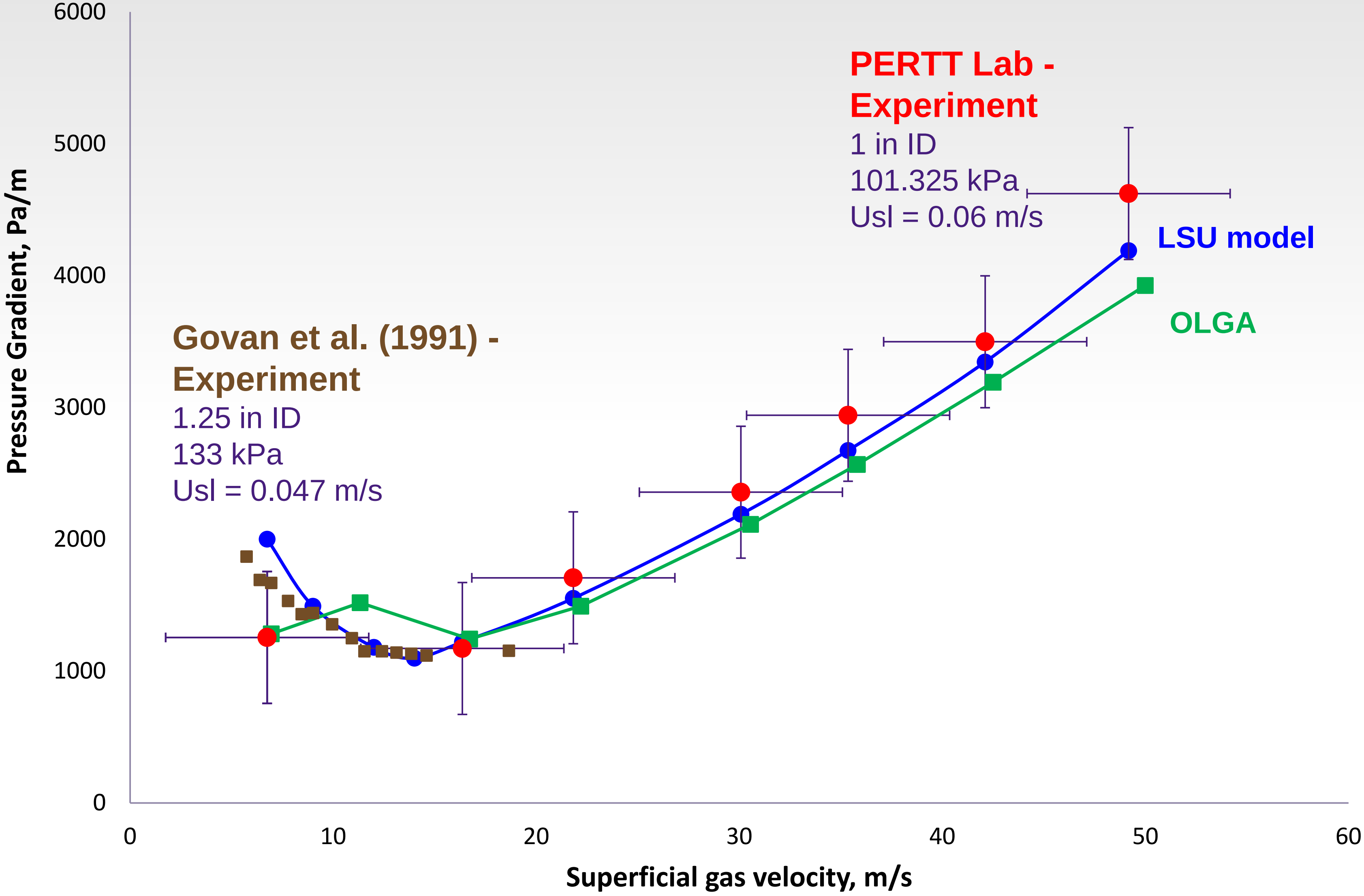
PT-320: -0.0

PT- 310: -6.4

Venturi 1 dP (inH2O): 2.73433 SCFM: -1.0

Venturi 2 dP (inH2O): 0.143961 SCFM: 11.0

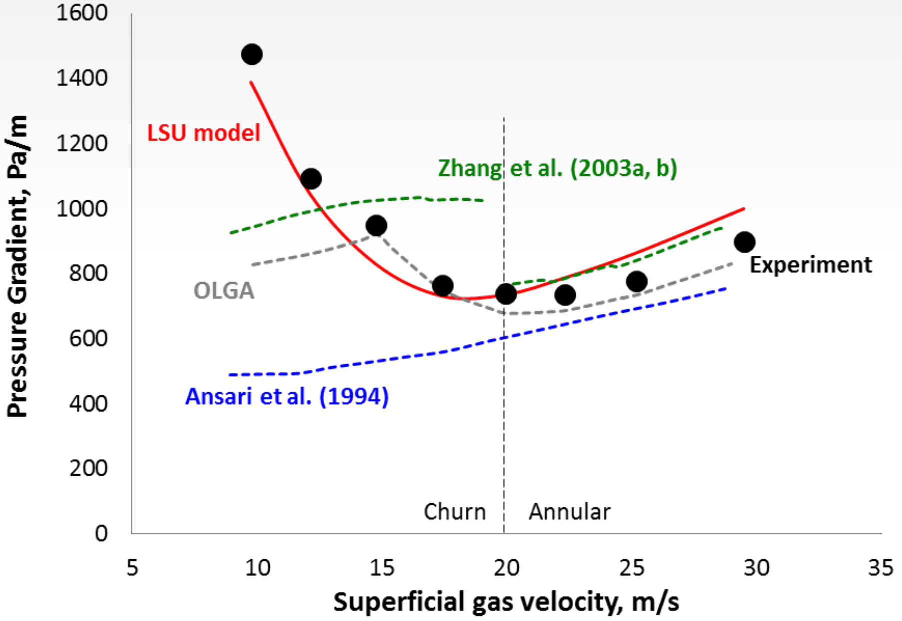
Experimental Data Quality Check



Can the Current Models be Improved?

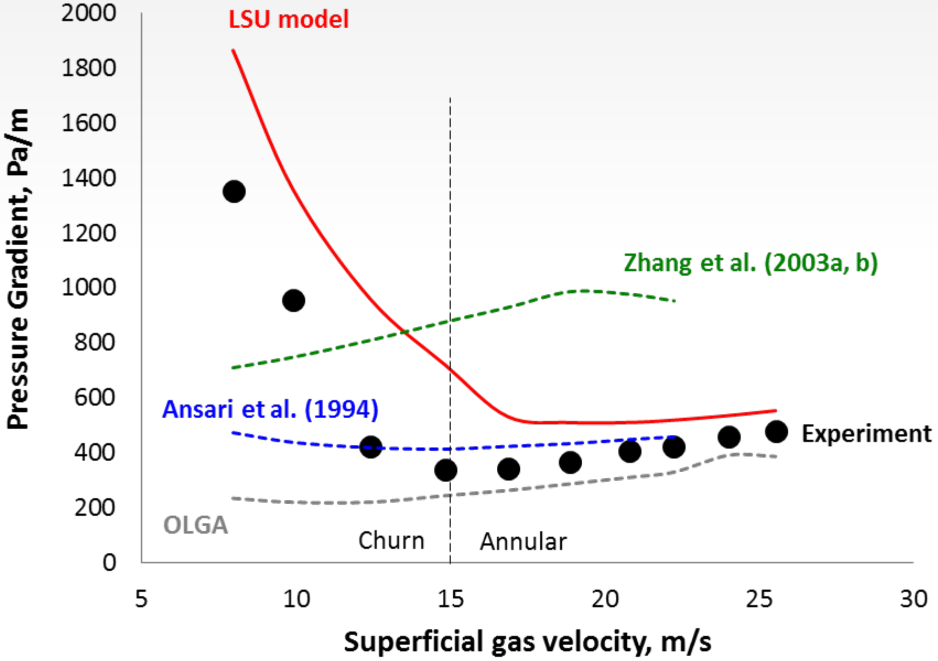
- We believe **its is possible!!!**

d = 2-in



U_{LS} = 0.05 m/s

d = 4-in

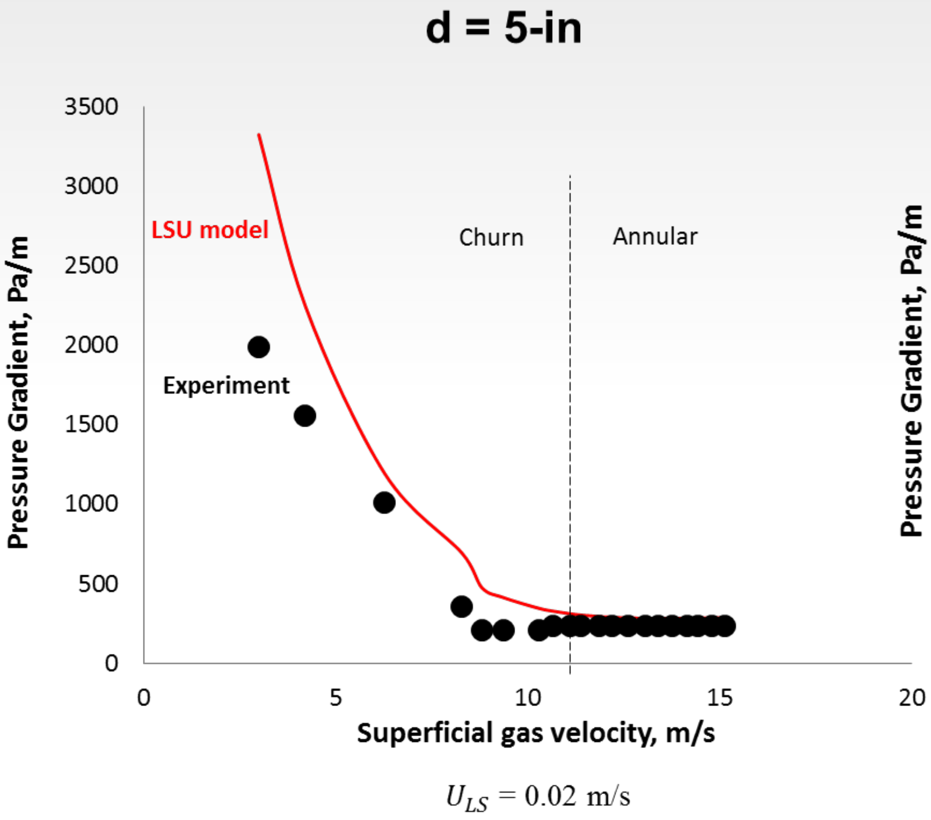


U_{LS} = 0.05 m/s

(modified after Skopich et al., 2015)

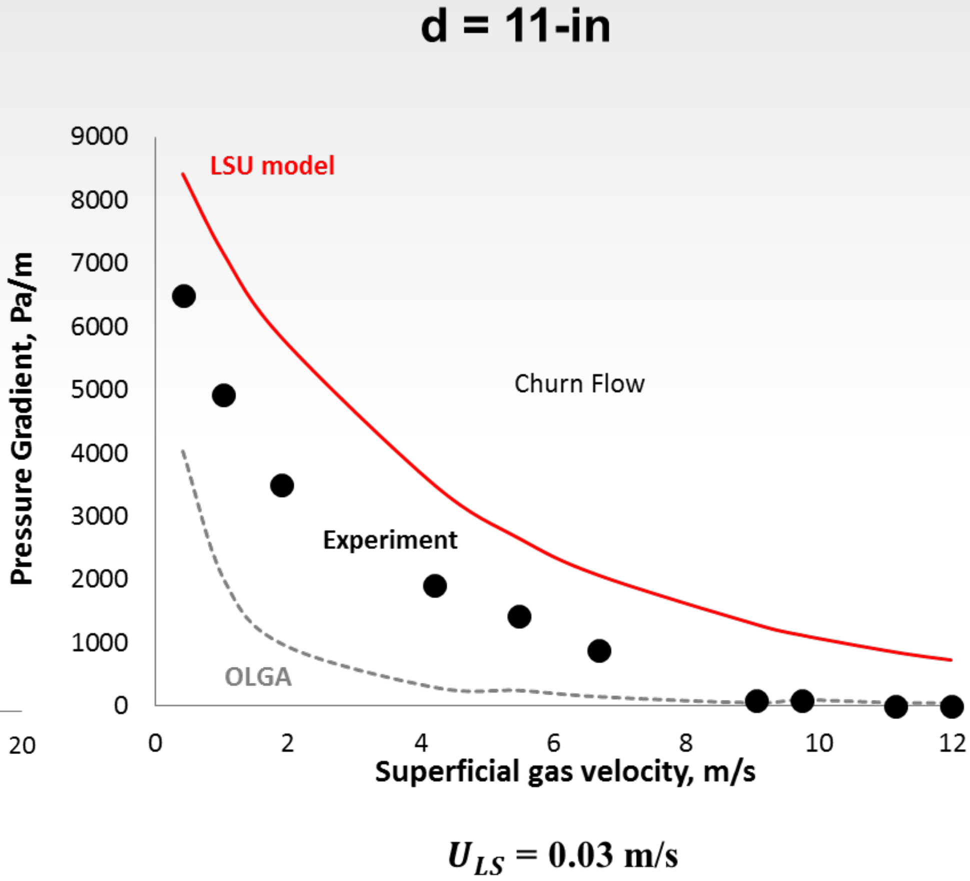
Can the Current Models be Improved?

- ❑ Even for **large pipe diameters!**



$U_{LS} = 0.02$ m/s

(Van der Meulen, 2012)



$U_{LS} = 0.03$ m/s

(Zabaras et al., 2013)

Final Remarks

- ✓ We have done a **significant amount of work in 4 months**. We are on schedule!!!
- ✓ It is still **extremely challenging** to point out a **single method** for a wide variety of WCD conditions
- ✓ **Different methods** may be suggested for **different fluid and flow conditions**, making the **recommended practice field specific** depending on reservoir and fluid properties.
- ✓ **Further investigations** of benchmarking and **calibration** of exiting WCD models against representative **field and fluid WCD conditions is needed!**
- ✓ Experimental Setup Design and construction **is following the schedule**

Final Remarks

- ✓ Based on preliminary comparisons, **significant improvement** can be achieved on **wellbore flow models for WCD calculations**

Next Steps

- ☐ Try to get field data for large diameter pipe and large flow rates, to assess validity of wellbore flow models
- ☐ Compare WCD calculations between different commercial packages (PETEX and HIS), but using the same wellbore flow models
- ☐ Finish installation of 12 in test section for experimental set up
- ☐ CFD upscaling model results
- ☐ Generate experimental data at PERTT Lab for large pipe diameter and large flow rates
- ☐ Compare wellbore flow models to experimental data