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T U F F P

Tulsa University Fluid Flow Projects

January 2004 **Volume 18, Issue 1**

Editorial by Cem Sarica

We enter 2004 with an increase in our membership. I am happy to announce that YUKOS Oil of Russia joined TUFFP. Efforts are underway to increase the membership. We hope to gain more members during 2004.

The current phase of the Tulsa University Paraffin Deposition Projects (TUPDP) will be completed on March 31, 2004. The next three-year phase will start on April 1, 2004. This phase of the project will focus on model and software development, supported by experimental studies.

The Hydrate Flow Performance JIP (TUHFP) has officially started, with significant support from DeepStar. The first phase of the study will last two years. The University of Tulsa and the Colorado School of Mines Hydrate research group will be collaborating.

Dr. Hong-Quan (Holden) Zhang's promotion to a Faculty position in the Petroleum Engineering Department and increased research activity prompted our efforts to fill two Research Associate positions, one for TUPDP and one for both TUFFP and TUCoRE. The search process is currently underway. Three candidates will be interviewed in January 2004. The positions are expected to be filled before the Spring 2004 Advisory Board meetings.

A major effort is underway to improve software deliverables to our members. The objective of the effort is to improve and increase the use of the developed multiphase technology by our membership. Microsoft's Excel platform has been selected as the interface, regardless of the scientific programming language such as FORTRAN, C++, etc.

Progress on each research project is given later in this Newsletter. A brief summary of the activities is given below.

The main objective of the severe slugging study is to investigate severe slugging occurrence, prediction and elimination for gas-oil-water flow. The TUFFP severe slugging test facility is currently being modified to operate with three-phase flow. The facility will be commissioned by Mid April, and the testing program will start in May 2004.

The slug tracking project aims at developing a well documented, robust, slug-tracking model for slug flow in hilly-

terrain pipelines. The coding of the model has been started and is expected to be completed by Summer 2004.

Efforts continue on modifications to the 6-in. flow loop and on modeling studies in the low liquid loading gas-liquid flow in near-horizontal pipes project. Facility modifications include structural changes to incline the facility with ease. A two-fluid model based on the double-circle assumption is being developed to predict the pressure gradient, liquid holdup, wetted perimeters, and liquid film thickness at the bottom in low liquid loading stratified flow for given operation conditions, liquid properties and pipeline orientation.

An assessment study continues on three-phase flow technology to identify the gaps and weaknesses in our models and to develop a preliminary model. TUFFP oil-water flow facility has been upgraded to a three-phase, gas-oil-water facility to experimentally investigate gas-oil-water flow in horizontal and slightly inclined pipes. Three phase flow testing was started last Fall. Currently, activities are focused on modeling.

Oils with viscosities as high as 10,000 cP are produced from many fields around the world. Current multiphase flow models are largely based on experimental data with low viscosity fluids. Thus, the gap between actual lab data and field data may be three orders of magnitude or more. Currently, a newly designed facility is being set-up in the Model Lab for the experimental part of this study. The facility will consist of a 64.0-ft long pipe with a 27.0-ft visualization section. Testing is expected to begin before Fall 2004.

As part of our up-scaling studies, efforts are underway to collect available high pressure and large diameter pipe data. The original high pressure SINTEF data are expected to become available for use in our studies. Moreover, additional data from various companies may become available. A careful analysis of the data will lead to better design of any experimental program that we might pursue in the future, including SF6 studies as considered earlier.

In multiphase flows, there are many cases where droplets are entrained from or coalesced into a continuous homo-phase. For example, in annular mist flow the liquid droplets are in dynamic equilibrium with the film on the walls, experiencing both entrainment and coalescence. Similarly, in oil-water flows, the observed mixing and/or separation involve both entrainment and coalescence. Very few mechanistic models exist for entrainment rate and coalescence rate. Understanding the basic physics of these phenomena are essential to model situations of practical interest to the industry, such as separator designs or chemical injection ports for corrosion control. A new TUFFP project has been initiated to investigate droplet-homophase interaction.

Dr. Hong-Quan (Holden) Zhang Named Associate Director of TUFFP

Effective January 2, 2004, Dr. Hong-Quan Zhang, an Assistant Professor of Petroleum Engineering, was appointed Associate Director of TUFFP. For several years, Holden has been serving in this capacity without the title. His activities include directing or co-directing TUFFP projects, preparation of progress reports, preparing students for Advisory Board meetings, and preparation of the semi-annual TUFFP newsletter. Holden is also serving as co-principal investigator in a TUCoRE project titled “High Viscosity Multiphase Flow” funded by ChevronTexaco.

In addition to his research activities, Holden serves as an Assistant Professor in the Petroleum Engineering Department. With his addition to the Faculty, the department has further strengthened its emphasis on Multiphase Production and Flow Assurance subjects. Holden taught a graduate level course on Transient Multiphase Design last Fall and is currently teaching a Flow Assurance course for undergraduate students.

New Research Assistant

Ms. Gladys Sucre, from Venezuela, joined our team in the Fall 2003 to pursue her MS degree in Petroleum Engineering. Gladys received her BS degree in Chemical Engineering from Metropolitana University in Caracas, Venezuela in 2000. Gladys has been assigned to a project in the Paraffin Deposition Projects focusing on the kinetics of paraffin deposition.

Dr. Harvey Hensley and Suzette Blankenship Leave

Dr. Harvey Hensley has been volunteering as a Senior Research Associate with TUFFP/TUPDP since the Fall of 2002. He has decided not to continue in this capacity, effective Fall 2003. He has contributed significantly to Paraffin Deposition Projects with his own modeling efforts and through helping graduate students in their research projects. We sincerely appreciate his contributions and wish him well for his future endeavors.

Suzette Blankenship, the Project Assistant with TUFFP and TUCoRE, decided to transfer to another position at The University of Tulsa. We wish her well. Currently, a search process is underway to find her replacement.

Computer Manager Search

Jose Aramburu completed his BS degree during the Summer 2003. His employment was continued as a temporary staff member until January 5, 2004, when he accepted a full time position as a flow loop operator with the new Hydrate Flow Performance JIP at the University of Tulsa. A search has been initiated for his replacement. He will be available for emergencies until his replacement is found.

Newest TUFFP/TUPDP Alums

Mr. Jose Daniel Alana, Mr. Changhong (Charlie) Gao and Ms. Nilufer Kilincer have successfully completed their graduate studies. Jose's thesis was on the investigation of paraffin deposition characteristics of CBI oil. Jose has already accepted a position with the Hydrate Flow Performance JIP at The University of Tulsa. Charlie's research project was on the investigation of Long Term Paraffin Deposition Behavior. Nilufer studied Multiphase paraffin deposition experimentally. We thank Jose, Charlie and Nilufer for their contributions to TUPDP and welcome them to the ranks of TUFFP/TUPDP alumni. We wish the best for them in their future endeavors.

Update on Post Doctoral Research Associates Search

The promotion of Dr. Hong-Quan (Holden) Zhang to a Faculty position in the Petroleum Engineering Department, together with increased research activity has prompted our efforts to fill two Research Associate positions. One position is for TUPDP and the other position is for both TUFFP and TUCoRE. The search process is currently underway. One candidate for the TUPDP research associate position was interviewed and offered a position in November 2003. Unfortunately, the candidate accepted another position with a pharmaceutical company. Three more candidates will be interviewed in January 2004. Both positions are expected to be filled before the Spring 2004 Advisory Board meetings.

Web Site News!

All past TUFFP publications are now available on the web site. We are currently working on making all past data and software available. It is our plan to have this completed before the Spring 2004 Advisory Board Meeting.

TUFFP Financial Status

TUFFP's financial status remains stable for 2004. We entered 2003 with approximately $301,000 in our reserve fund. Our 2003 membership income is $420,000 from 12 members. Our total expenditures for 2003 are estimated to be $ 490,000. The difference of $70,000 will be covered from the reserve account, lowering the reserve balance to $230,000. 2004 income will be $455,000 from 13 members. With the significant increase in our activities and an increase in overhead charges, the 2004 expenditures are estimated to be around $500,000, further reducing the reserve balance to $185,000. Therefore, an increase in the membership fees is being considered for 2005, since no increase in membership fees have occurred for five consecutive years.

Flow Assurance is Offered to Undergraduate and Graduate Students

Dr. Holden Zhang is teaching a new course entitled "Flow Assurance" for the graduate and undergraduate students. Flow assurance has been an emerging multi-disciplinary subject addressing the hydrocarbon production from offshore fields. This course will systematically cover the prediction, prevention and remediation of various solid plug and deposits that may hinder fluid flow in petroleum production. Major subjects include fluid flow calculations, fluid characterization, hydrate formation and prevention, paraffin deposition, asphaltene problem, scale and transient operations.

Space Utilization

The current TUFFP Library was remodeled as office space for Dr. Holden Zhang, Assistant Professor of Petroleum Engineering. The office space formerly known as the Periodical Library has been converted into a General Library, combining the TUFFP Library and the Periodical Library.

Cengizhan Keskin to Defend His Ph.D. Proposal

Mr. Cengizhan Keskin is scheduled to defend his Ph.D. proposal entitled "An Experimental and Modeling Study of Gas-Oil-Water Flow in Horizontal and Slightly Inclined Pipes" on January 30, 2004. He expects to continue with his research as summarized in the progress report later in this Newsletter.

TUFFP Membership and Support

I am happy to announce that Yukos Oil of Russia recently joined TUFFP for 2004. With this addition, the TUFFP 2004 membership currently stands at 13, 12 industrial companies and MMS. DOE supports TUFFP in the development of new generation multiphase flow predictive tools for three-phase flow research. DOE's support translates into the equivalent 4 additional members for five years, effective July 2003.

Efforts are underway to increase TUFFP membership. Petrobras and Simsci have recently indicated their intention to rejoin TUFFP. Landmark Graphics and Shell Global Solutions have recently shown significant interest in TUFFP.

Software Improvement

A major effort is underway to improve the software deliverables to our members. The objective of this effort is to improve and increase the use of the developed multiphase technology by our membership. Microsoft's Excel platform was selected as the interface, regardless of the scientific programming language such as FORTRAN, C++, etc. After completion of a pilot project involving TUFFP's Flow Pattern Prediction Software, user friendly interfaces were developed for the Unified Model Program and the TUFFP Core Program, which contains eleven pressure drop and liquid holdup prediction methods.

Meetings/Conferences

Spring 2004 Advisory Board Meetings

Plans have now been finalized for the Spring 2004 Advisory Board meetings. A tour of the test facilities will be held on Tuesday, March 30 at 3:00 p.m. Following the tour, there will be a joint TUFFP/TUPDP BBQ between 5:00 - 7:00 p.m. The TUFFP Advisory Board meeting will be held at the Renaissance Tulsa Hotel and Convention Center. The meeting will begin at 8:30 a.m. on Wednesday, March 31 and will adjourn at 5:00 p.m. Following the TUFFP meeting, there will be a joint TUFFP/TUPDP reception from 6:00—9:00 p.m. at the Renaissance. The TUPDP Advisory Board meeting will be held on April 1 at the Renaissance. The meeting will begin at 8:00 a.m. and will adjourn at 5:00 p.m. The Request for Information form and hotel information will be placed on the web page soon. All persons from your company that plan to attend the Advisory Board meetings, should complete and return these forms as soon as possible to help us plan the meetings. Information on the Advisory Board meetings can also be found on our web site at www.tufpc.org/tuffp/abminfo.asp. You can then follow the links for the Request for Information form. TUFFP Advisory Board meeting brochures will be available for members at the meeting and a concerted effort will again be made to have the combined brochure and slide copy available for downloading from the web site at www.tufpc.org/tuffp/abm_brochures.asp shortly before the meeting. The brochure will contain sufficient information to help each attendee actively participate in discussions on current and future research projects, financial matters, and operating procedures.

TUFFP Short Course

The 29th annual TUFFP Short Course on Two-Phase Flow in Pipes will be taught May 17 - 21, 2004 at the Adam's Mark Downtown Hotel. Drs. Sarica and Brill will be teaching the course. The course covers the most current, up-to-date-research performed at the Tulsa University Fluid Flow Projects (TUFFP) and Tulsa University Paraffin Deposition Projects (TUPDP). This five-day course will focus on the fundamentals of two-phase flow in piping systems encountered in the production and transportation of oil and gas.The registration fee schedule for the short course is given below:

TUFFP/TUPDP Member Companies

Per Person	$1,495
Group Discount - Per Person	$1,395

Non-Member Companies

Per Person	$1,995
Group Discount - Per Person	$1,895

A brochure advertising the short course will soon be mailed to TUFFP and TUPDP members. An electronic copy will be available through the TUFFP web page at www.tufpc.org. Interested persons are urged to enroll as soon as possible to help us plan the course.

2004 Fluid Flow Projects Membership

Baker Atlas

BP

ChevronTexaco

ConocoPhillips, Inc.

Marathon Oil Company

Minerals Management Service

PDVSA - Intevep

Pemex

Petronas

Saudi Aramco

Schlumberger

TOTAL

YUKOS

BHR Group Schedules 4th North American Conference on Multiphase Technology

Since 1991, TUFFP has participated as a co-sponsor of BHR Group Conferences on Multiphase Production. TUFFP personnel participate in reviewing papers, serving as session chairs, and advertising the conference to our members.

BHR Group's 4th North American Conference on Multiphase Technology will be held June 3-4, 2004 in the beautiful resort of Banff, Canada. Drs. Holden Zhang and Ryo Manabe will be presenting two technical papers based on TUFFP research. It is expected that the conference will benefit anyone engaged in the application, development and research of multiphase technology for the oil and gas industry.

Having Fun at Denver SPE Meeting!

Future Advisory Board Meetings

March 30, 2004
Tulsa University Hydrate Flow Performance JIP
Advisory Board Meeting
Allan Chapman Activity Center
8:00 a.m.—2:00 p.m.

TUFFP/TUPDP/TUHFP JIP
Tour of Test Facilities
University of Tulsa North Campus - Tulsa, OK
3:00 - 5:00 p.m.

TUFFP/TUPDP/TUHFP JIP
Barbeque
University of Tulsa North Campus - Tulsa, OK
5:00 - 7:00 p.m.

March 31, 2004
Tulsa University Fluid Flow Projects
Advisory Board Meeting
Renaissance Tulsa Hotel - Tulsa, OK
8:30 a.m. - 5:00 p.m.

TUFFP/TUPDP/TUHFP
Reception
Renaissance Tulsa Hotel- Tulsa, OK
6:00 - 9:00 p.m.

April 1, 2004
Tulsa University Paraffin Deposition Projects
Advisory Board Meeting
Renaissance Tulsa Hotel - Tulsa, OK
8:00 a.m. - 5:00 p.m.

September 21, 2004
Tulsa University Hydrate Flow Performance JIP
Advisory Board Meeting
Allan Chapman Activity Center
8:00 a.m.—4:00 p.m.

TUFFP/TUPDP/TUHFP JIP
Tour of Test Facilities
University of Tulsa North Campus - Tulsa, OK
4:00 - 5:30 p.m.

TUFFP/TUPDP/TUHFP JIP
Barbeque
University of Tulsa North Campus - Tulsa, OK
5:30 - 7:00 p.m.

September 22, 2004
Tulsa University Fluid Flow Projects
Advisory Board Meeting
Hotel to be Determined - Tulsa, OK
8:30 a.m. - 5:00 p.m.

TUFFP/TUPDP/TUHFP
Reception
Hotel to be Determined- Tulsa, OK
6:00 - 9:00 p.m.

September 23, 2004
Tulsa University Paraffin Deposition Projects
Advisory Board Meeting
Hotel to be Determined - Tulsa, OK
8:00 a.m. - 5:00 p.m.

Progress Updates

Experiments and Modeling of Gas-Oil-Water Flow in Horizontal and Slightly Inclined Pipes

Cengizhan Keskin

The ultimate goal of TUFFP for gas-oil-water studies is to develop a mechanistic model based on theoretical analysis and experimental results for the prediction of flow behavior during production and transportation of gas-oil-water in pipes. The objective of this study is to investigate three-phase flow of gas-oil-water in horizontal and slightly inclined pipes.

The experimental work is being conducted using the TUFFP facility for gas-oil-water flow. The facility consists of a closed circuit loop with the following components: pumps, heat exchangers, metering sections, filters, test section, separator and storage tanks. The test section is attached to a boom whose angle can be changed with a cable system and a vertical tower. The current test section is composed of two 69.3-ft (21.1-m) long straight transparent pipes, connected by a 4.0-ft (1.2-m) long PVC bend. The pipeline has a 2.0-in. internal diameter.

Some two-phase oil-water tests were conducted for horizontal pipe to commission the facility and reproduce the data of Trallero[1]. For the two-phase oil-water experiments, the oil superficial velocity and the water superficial velocity ranged from 0.025 m/s to 1.52 m/s and from 0.03 m/s to 1.4 m/s, respectively. Comparisons with the data of Trallero showed good agreement for the flow patterns and the pressure gradients.

Three-phase gas-oil-water testing has also been started. Keeping the water fraction constant at 20%, tests were performed for various gas, oil and water flow rates. Three-phase testing for different water fractions will resume in April 2004 after the last freeze date in Tulsa, OK.

Currently, efforts are focused on the modeling of three-phase gas-oil-water flow. The model evaluation study is still underway. Moreover, Mr. Keskin, a Ph.D. Research Assistant assigned to the project, will be defending his research proposal on January 30, 2004.

1. Trallero, J. L.: “Oil-Water Flow Patterns in Horizontal Pipes”, Ph.D. Dissertation, The University of Tulsa (1995).

Low Liquid Loading Gas-Liquid Flow in Near-Horizontal Pipes

Richard Fan

A more accurate prediction of pressure gradient and liquid holdup in near-horizontal, wet-gas pipelines is needed to better size pipelines and downstream processing facilities. The objective of this study is to investigate, experimentally and theoretically, low liquid loading gas-liquid two-phase flow in near-horizontal pipes, and to develop improved design models for wet-gas pipelines.

A 50.8-mm (2-in) diameter, 19-m long acrylic flow loop is being used for this study. Both air-oil and air-water low liquid loading two-phase flow experiments have been finished, with the inclination angle changing from -2° to 2° from horizontal. The measured parameters include gas flow rate, liquid flow rate, pressure, differential pressure, temperature, liquid holdup, liquid film flow rate and liquid entrainment fraction. Low liquid loading horizontal flow tests with gas velocities of 7.5 - 13.5 m/s and liquid velocities of 0.00075 – 0.05 m/s have been completed. The facility is being modified to facilitate various inclination angles, and more data for various inclinations will be taken after the Spring Advisory Board meeting.

Model development is still underway. A two-fluid model based on the double-circle assumption will

be developed to predict the pressure gradient, liquid holdup, wetted perimeters, and liquid film thickness at the bottom in low liquid loading stratified flow for given operation conditions, liquid properties and pipeline orientation.

Investigation of Occurrence and Elimination of Severe Slugging for Gas-Oil-Water Flow in Pipeline-Riser Systems

Carlos Beltran

Severe slugging can occur in multiphase flow, particularly in deep water petroleum production systems. Severe slugging can cause periods of no liquid and gas production into the separator, followed by very high liquid and gas flow rates. This phenomenon is very undesirable due to large pressure and flow rate fluctuations.

The main purpose of this study is to investigate severe slugging occurrence, prediction and elimination for gas-oil-water flow. In order to accomplish this, the objectives of the project will include:

1) Investigation of the characteristics of severe slugging for three-phase flow in the pipeline-riser facility, varying the water cut in the liquid phase;

2) Assess the applicability of two-phase severe slugging prediction models for three-phase flow, and develop improved models if necessary;

3) Better understanding of the physics of severe slugging for three-phase flows in a deep-water pipeline-riser system;

4) Investigate elimination techniques such as self-lifting, choking, gas lifting, etc. for three-phase flow.

Modifications to the severe slugging test facility continue. A water tank (10-ft tall and 4-ft ID) has been designed and built. This design will allow removal of separated oil from the water tank. A horizontal three-phase separator (20-ft long by 4.5-ft ID) has been purchased from the NATCO Group. The separation performance is expected to be 1% water/oil ratio and 1% oil/water ratio for water cuts between 5% and 95%. An additional gas-lift line and a choke upstream of the riser top separator are being added to facilitate external gas-lift and choking, respectively, as severe slugging elimination techniques.

Once the TUFFP severe slugging test facility is modified, the current data acquisition program will be updated and additional instruments will be added and calibrated. The experimental work will be started after Spring 2004 Advisory Board meeting.

Slug Tracking Model Formulation

Leslie Thompson

The objective of this study is to develop a well documented, robust, slug-tracking model for slug flow in hilly-terrain pipelines. The model will be written in a manner conducive to easy modification to include alternative boundary and closure relationships.

Since the last ABM, Dr. Yehuda Taitel was contacted and lengthy (e-mail) discussions on his slug tracking model published in the March 2000 SPEJ were made. Dr. Taitel provided valuable insight into the reasoning underlying formulation of the model, clarified some of the model equations, and provided further details on the calculation sequence. However, some of the crucial details on treatment of flow at elbows, slug dissipation and slug merging are still unresolved. With our current understanding of the model, the coding of the model has begun, and as the modeling/coding proceeds, Dr. Taitel's original FORTRAN code will be referred to for guidance.

In the October, 2003 ABM, our stated goal was to complete coding of the model by May 2004; at present, we are cautiously optimistic that this goal can be met.

Qian Wang

Upscaling Studies in Multiphase Flow

One of the most important issues that we face in multiphase flow technology development is scaling up of small diameter and low pressure results to large diameter and high pressure conditions. Studies with a large diameter facility would significantly improve our understanding of flow characteristics in actual field conditions.

Efforts are underway to collect available high pressure and large diameter pipe data. The original SINTEF high pressure data are expected to be made available for use in our studies. Moreover, additional data from various companies may also be made available. Careful analysis of the data will lead us to better design any experimental program that we might pursue in the future, including SF6 studies as planned earlier.

Unified Model for Gas-Liquid Flow in Wells and Pipelines

Holden Zhang

The TUFFP unified hydrodynamic model was developed for predictions of flow pattern transitions, pressure gradient, liquid holdup and slug characteristics in gas-liquid pipe flow at different inclination angles from -90 to 90 deg. The model has been validated with extensive experimental data acquired with different pipe diameters, inclination angles, fluid physical properties, gas-liquid flow rates and flow patterns. The Fortran computer program for the unified model has been integrated with an Excel interface to make it more user friendly.

This is an ongoing project. Further validations and modifications will be made when new experimental results are available and new closure relationships are developed.

Effect of High Viscosity on Multiphase Flow Behavior

Bahadir Gokcal

High viscosity oils are produced from many fields around the world. Oil production systems are currently flowing oils with viscosities as high as 10,000 cP. One known field is being pumped below its pour point. The current models for multiphase flow are largely based on experimental data with low viscosity fluids. Commonly used laboratory oils have viscosities less than 5 cP with rare instances of 20 cP. Thus, the gap between actual lab data and field data can be three orders of magnitude or more. This project is of particular interest to deepwater operations.

Existing predictive models include viscosity as an intrinsic variable. Multiphase flows are expected to exhibit significantly different behavior with high viscosity oils. Many different phenomena will be affected by a high viscosity fluid, including droplet formation, surface waves, bubble entrainment, slug mixing zones, and even three phase stratified flow. The flow pattern transitions and pressure drop predictions need to be experimentally determined, and the models need to be modified to account for any discrepancies. Furthermore, the impact of low Reynolds number oil flows in combination with high Reynolds number gas and water flows may yield new flow patterns and concomitant pressure drop models.

The TUFFP 2.0-in. diameter low liquid loading facility has been dismantled to make room for high viscosity multiphase flow research. Currently, a new test facility consisting of a 64.0-ft long pipe with a 27.0-ft visualization section is being constructed. Testing is expected to begin after Spring 2004. Initially, flow patterns will be identified, and pressure gradient and liquid hold-up will be measured during the tests.

Experimental results will be compared with predictions from different mechanistic models in order to select the best model for which modifications or new development will be made.

Closure Laws for Droplet-Homophase Interaction

In multiphase flows, there are many cases where droplets are entrained from or coalesced into a continuous homo-phase. For example, in annular mist flow the liquid droplets are in dynamic equilibrium with the film on the walls, experiencing both entrainment and coalescence. Similarly, in oil-water flows, the observed mixing and/or separation involve both entrainment and coalescence.

Very few mechanistic models exist for entrainment rate and coalescence rate. Understanding the basic physics of these phenomena is essential to model situations of practical interest to the industry, such as separator designs or chemical injection ports for corrosion control. Indeed, there are no good models for film thickness or flow rates, due to the mass and momentum exchanges between the mist and the film. A good understanding of the physics of these phenomena will also help us understand the basis of many of the pressure drop and holdup correlations used in current pipeline simulators.

This project has been initiated with a literature search and review. It will continue with an existing computation fluid dynamics model (CFD) to simulate the physics and refining that model based on directed experiments. The experiments will gather three-dimensional information such as mist versus film mass flow rates, droplet distributions, 3D velocity fields, drop size measurements, etc. New instrumentation, test sections, and methodologies will be required to obtain the desired information. Different experimental methods such as X-ray tomography are being examined for possible application to this study.

Related Research

Paraffin Deposition Projects

"Charlie" Gao

Small Scale Studies

A new Small Scale Loop was constructed to conduct research on long term paraffin deposition behavior and aging phenomena. South Pelto crude oil was used as the testing oil.

Several aging tests were conducted. The experimental results were compared with predictions from a wax deposition prediction model called TUWAX developed at The University of Tulsa. Some agreement was observed between the experimental results and the model predictions. The effects of Reynolds number, velocity and shear stress on the deposition behavior were also investigated. Reynolds number was found to have the most effect on the deposition rate.

Oil-water two-phase tests using three different water cuts, 25%, 40% and 75% were conducted to investigate the impact of water on paraffin deposition. No reduction in deposition thickness was observed with increasing water cut.

Jose Alana

Single-Phase Studies

Single-phase paraffin deposition was investigated in a 50-m (164-ft) long, 43.6-mm (1.71-in.) inside diameter test facility. The objective was to study the effect of high viscosity on the deposition process. Two tests were conducted with Garden Banks condensate to study the effect of flow direction on the paraffin deposition phenomena. A test matrix with a total of 17 tests was completed with Cote Blanche Island crude oil from ChevronTexaco to study the dependence of the deposition process on oil inlet temperature, flow rate, temperature difference between the oil and the glycol, and deposition time with a relatively heavy and viscous oil.

The performances of previous models, specifically an equilibrium model with variable wax fraction, and a non-equilibrium model, were evaluated with a heavier and more viscous oil in the present study. These models tend to over predict the thickness of the deposit.

Nilufer Kilincer

Two-Phase Studies

Paraffin related problems can occur at almost every stage of oil and gas production. Paraffin problems result from the cooling of the hydrocarbon mixtures below the wax appearance temperatures (WAT) and subsequent precipitation and deposition of high molecular weight hydrocarbons during transportation of these mixtures.

Multiphase paraffin deposition under different flow patterns in horizontal and vertical pipes was studied as part of Tulsa University Paraffin Deposition Projects (TUPDP) research consortium. Several multiphase paraffin deposition tests with Garden Banks condensate from the Gulf of Mexico and Tulsa City natural gas were conducted in a high-pressure state-of-the-art test facility with an inside pipe diameter of 52.5 mm for both horizontal and vertical conditions. The wax deposit thicknesses were measured using direct (online and offline Liquid Displacement and Level Detection (LD-LD)) and indirect techniques (heat transfer and pressure drop).

Observations of flow pattern dependent behavior on paraffin deposition are reported, and possible causes of the different deposition behavior for different flow patterns are discussed. Moreover, a comparative analysis is given of the multiphase deposition characteristics of South Pelto oil from the Gulf of Mexico (previously studies at TUPDP) and Garden Banks condensate using the same natural gas.

Three-Phase Studies

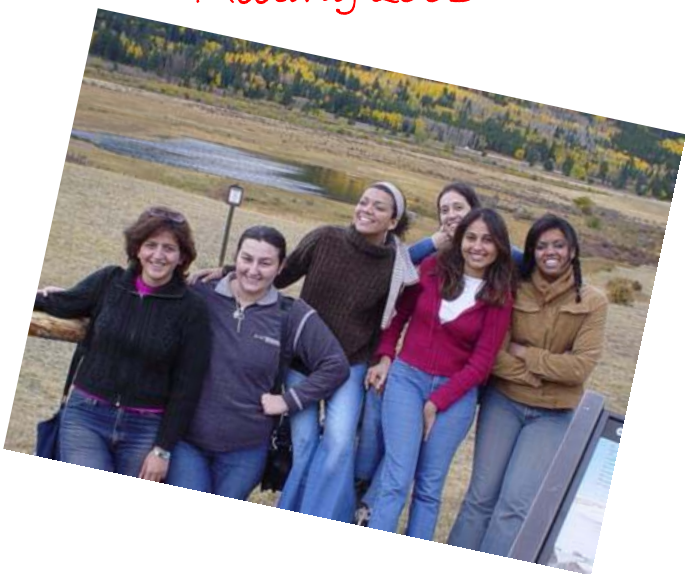
Guilherme Couto

Cold finger experiments with emulsions are ongoing in order to investigate wax deposition in the presence of water. The cold finger device allows running up to four different tests simultaneously with rotational speeds up to 500 rpm. Tests with different water cuts using fresh water and brine are being conducted and wax deposition has been verified to be a function of the temperature difference between the bulk and the cold finger. Also scheduled are longer-term two-phase deposition tests with the Small Scale Loop using brine with different water cuts . These tests will be performed simultaneously with the cold finger tests. The fluids to be investigated are South Pelto and Cote Blanche Island crude oils.

TUCoRE Projects

Several of our research personnel are involved in ChevronTexaco's TUCoRE initiative. Currently, a High Viscosity Multiphase Flow project is underway.

More Fun at Denver SPE Meeting 2003



Calendar of Events

2004

March 30	Tulsa University Hydrate Flow Performance JIP Advisory Board Meeting—Tulsa, Oklahoma
	TUFFP/TUPDP Facility Tour and Barbecue
March 31	Tulsa University Fluid Flow Projects Advisory Board Meeting—Tulsa, Oklahoma
April 1	Tulsa University Paraffin Deposition Advisory Board Meeting—Tulsa, Oklahoma
April 25—29	2004 Spring National Meeting (AIChE), Hyatt Regency, New Orleans, Louisiana
April 28—30	Electric Submersible Pumping Systems—SPE Gulf Coast Section Workshop—Houston, Texas
May 3—6	Offshore Technology Conference—Houston, Texas
June 3—4	4th North American Conference on Multiphase Technology (BHRg) - Banff, Canada
July 25—29	ASME Heat Transfer and Fluid Engineering Summer Conference—Charlotte, North Carolina
September 21	Tulsa University Hydrate Flow Performance JIP Advisory Board Meeting—Tulsa, Oklahoma
	TUFFP/TUPDP Facility Tour and Barbeque
September 22	Tulsa University Fluid Flow Projects Advisory Board Meeting—Tulsa, Oklahoma
September 23	Tulsa University Paraffin Deposition Projects Advisory Board Meeting—Tulsa, Oklahoma
September 26—29	SPE Annual Technical Conference and Exhibition—Houston, Texas
October 18—20	Asia Pacific Oil and Gas Conference and Exhibition—Perth, Australia
November 14—18	International Conference on Heavy Organic Deposition (HOD), Presidente Intercontinental Hotel—San Jose del Cabo, BCS, Mexico

2005

May 2—5	Offshore Technology Conference—Houston, Texas