THE UNIVERSITY of TULSA

TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

Summer 2001 | A Semiannual Publication | Volume 15, Number 2

Director
Cem Sarica (918) 631-5154
sarica@utulsa.edu
Director Emeritus
James P. Brill (918) 631-5114
brill@utulsa.edu
Co-Principal Investigator - TUPDP
Mike Volk (918) 631-5127
michael-volk@utulsa.edu
Senior Research Associates
Emmanuel Delle-Case (918) 631-5146
emmanuel-delle-case@utulsa.edu
Holden Zhang (918) 631-5142
hong-quan-zhang@utulsa.edu
Research Associate
Qian Wang (918) 631-5107
qian-wang@utulsa.edu
Project Assistant
Pamela M. Clark (918) 631-5111
clarkpm@utulsa.edu
Administrative Secretary
Linda M. Jones (918) 631-5110
jones@utulsa.edu
Senior Research Technicians
Tony Butler (918) 631-5147
roy-butler@utulsa.edu
Charles Ingle (918) 631-5120
charles-ingle@utulsa.edu
Research Technicians
Howard Rettig (918) 631-5133
howard-rettig@utulsa.edu
Craig Waldron (918) 631-5131
craig-waldron@utulsa.edu
Research Assistants
Eissa Al-Safran (918) 631-5119
eissa-al-safran@utulsa.edu
Xin Chen (918) 631-5117
xin-chen@utulsa.edu
Yongqian Fan (918) 631-5118
yongqian-fan@utulsa.edu
Changhong Gao (918) 631-5145
changhong-gao@utulsa.edu
Oris Hernandez (918) 631-5143
oris-hernandezperez@utulsa.edu
Cengizhan Keskin (918) 631-5117
cengizhan-keskin@utulsa.edu
Nilufer Kilincer (918) 631-5145
nilufer-kilincer@utulsa.edu
Ryo Manabe (918) 631-5119
ryo-manabe@tulsa.edu
Jarl Tengesdal (918) 631-5109
jarl-tengesdal@utulsa.edu
Workstation Manager
Dan Underwood (918) 631-5115
dan-underwood@utulsa.edu
Fax Number: (918) 631-5112
TUFFP www.tuffp.utulsa.edu
TUPDP www.tuwax.utulsa.edu

New Beginnings

During recent years, our industry has been through a significant transformation due to mergers and buyouts. It may not be unrealistic to expect more of that in the near future. These changes are expected to have their effects on research and development needs, and the priorities and strategies of newly formed companies. I would like to emphasize that TUFFP will be responsive and adaptive to the changes to address the needs of our membership.

Our industry requires the development of new technologies and/or the improvement of existing ones in the multiphase flow and flow assurance areas. Being actively involved in multiphase flow technology development over the past 29 years, TUFFP has a lot to offer to a wide spectrum of companies, including major and independent oil and gas producers, and service and engineering consulting companies that are involved in the development and deployment of multiphase flow technologies. Our plans call for becoming more responsive to short term technology needs. We will increase our efforts to reach out to companies who have significant interest in multiphase flow and flow assurance issues.

Since January 2001, we have been aggressively working on building our team to invigorate the consortia activities. Our efforts have begun to bear fruit. Over the last several months, there have been several additions to our family. We have a new technician and a new workstation manager. We have also welcomed five new students. Two Ph.D. and one M.S. students will be assigned to projects within TUFFP while one Ph.D. and one M.S. student will be assigned to TUPDP projects. We are also in the process of advertising for post-doctoral research associate positions. We hope to add two more research associates and several more graduate students to our team by early 2002.

TUFFP activities are summarized later in this Newsletter. The development of a new generation unified mechanistic model that can be used with greater confidence when designing multiphase facilities in the field is near completion. The final report on the development of the model along with the computer program will be distributed to TUFFP members in August 2001. Improvement efforts on the flow pattern map generation program, FLOWPAT II, are underway. Ryo Manabe is about to complete his studies towards improving our abilities to predict multiphase flow local heat transfer phenomena for different flow patterns in wells and pipelines. Eissa Al-Safran has started to analyze his data. Early results reveal interesting characteristics of two-phase flow in hilly terrain pipelines. The low liquid loading gas-liquid flow in near-horizontal pipes project continues with experimental tests for different inclination angles. One of the new students will be assigned to this project. Oil-water-gas flow has consistently received high rankings over several years in our questionnaires. We will initiate oil-water-gas three-phase flow research at TUFFP this fall. The oil-water facility will be modified for this project.

Within the context of addressing the specific needs of our member companies, we have recently embarked on two new projects. The focus of a new joint industry project is the investigation of a novel technique for the elimination of severe slugging in ultra deep-water production systems. The second project is a contract project fully funded by one of our members. The main objective is to investigate orifice plates as steam quality and mass flow rate measurement devices.

We are currently pursuing two major initiatives. The University of Tulsa has received a letter of intent for relocation of Marathon's state of the art Hydrate flow loop from Littleton, Colorado, to the North Campus of The University of Tulsa. Efforts are underway to form a new Joint Industry Project

to conduct research on Hydrates. The other initiative is part of a Chevron Center of Excellence at the University of Tulsa. Multiphase flow and flow assurance research was identified as one of the focus areas of the center. A proposal has been submitted to Chevron to establish a Flow Assurance Center that can investigate essentially all fluid flow problems related to deep-water production of oil and gas.

These are exciting times and new beginnings for us at the Fluid Flow Projects. A synopsis of our current and future activities is given in this newsletter.

Our Family Grows!

Since January 2001, we have been aggressively working on building our team to invigorate the consortia activities. Our efforts have started to bear fruit. Recently, there have been several additions to our family.

Cengizhan Keskin

We have welcomed five new students. I would like to introduce them to you. Mr. Cengizhan Keskin is pursuing a Ph.D. degree at the University of Tulsa. He received his B.S and M.S. degrees in Petroleum and Natural Gas Engineering from the Middle East Technical University in Turkey. His MS thesis research involved both laboratory and modeling studies of fossil fuel characterization. Mr. Keskin's research interests are in the general areas of single-phase and multiphase flow, drilling fluid hydraulics, wellbore mechanics and enhanced oil recovery.

Xin Chen

Mr. Xin Chen, from the Peoples Republic of China, received his B.S. degree in Oil Mechanical Storage and Transportation Engineering from Logistic Engineering Institute in July, 1994. He has worked as a petroleum engineer for Luoyang Petrochemical Engineering Corporation in China for seven years. His work scope was to design long distance pipelines, oil tank farms and high temperature flares. He will pursue an M.S. degree in Petroleum Engineering at the University of Tulsa.

Yongqian Fan

Mr. Yongqian Fan, from the Peoples Republic of China, received his B.S. and M.S. degrees in Petroleum Engineering from the University of Petroleum. Cengizhan, Xin and Yongqian will be assigned to new TUFFP projects.

Mr. Changhong Gao, also from the Peoples Republic of China, received his B.S. degree in Petroleum Engineering from the University of Petroleum with a 3.97 GPA in 1999. He has worked for two years with Sino Petroleum Chemical Company working in the Shengli Oil Field, the second largest oil field in China. Changhong served as a work-over engineer, production engineer and a cost supervisor.

Changhong Gao

Ms. Nilufer Kilincer, from Turkey, has received her B.S. and M.S. degrees in Petroleum Engineering from Middle East Technical University. She comes to us with significant experience in experimental research. Mr. Gao and Ms. Kilincer will be assigned to a TUPDP research project towards fulfilling their degree requirements.

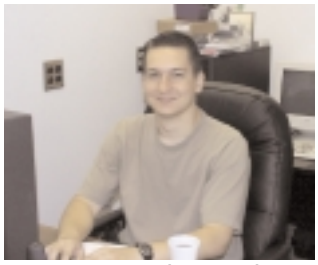
Nilufer Kilincer

Mr. Craig Waldron is the newest addition to our technician pool. Craig was hired as an Electronics Research Technician to assist Tony Butler with our growing electronics needs. He will also serve as a flow loop operator for TUPDP. Craig brings with him 20 years of experience as a Senior Research Technician at Conoco in Ponca City and has a strong background in instrumentation, data acquisition, operating analytical equipment, safety and working with hazardous materials.

Craig Waldron

We are also happy to announce that Dan Underwood has rejoined us after a brief departure. Recognizing the increased computing needs of the entire North Campus, we are working on creating a new position, North Campus Workstation Manager, to better address the needs of the consortia and Joint Industry Projects.

Due to the increased activities within the existing consortia, and new research initiatives, we plan to add two more post-doctoral research associates to our team by January 2002. Advertisements for the positions will appear in the Journal of Petroleum Technology.



Dan Underwood

Promotions within TUFFP/TUPDP

Mr. Emmanuel Delle-Case and Dr. Holden Zhang have recently been promoted to senior research associate positions. We congratulate them for their well-deserved promotions.

Emmanuel Delle Case

Emmanuel has proven to be an exceptional member of our team with outstanding capabilities in experimental research and experience in safety and environmental issues. He currently devotes his efforts to TUFFP, TUPDP, and Severe Slugging JIP activities. His

responsibilities involve supervising Research Technician activities, data acquisition and processing software, safety, training, designing and implementing process control aspects of flow loops, and some modeling activities. In addition to his current activities, he will be one of the key personnel in the future Hydrate JIP and Chevron Center of Excellence Initiatives.

Holden Zhang

Holden Zhang has a Ph.D. (1988) degree in Fluid Mechanics from Tianjin University in China. He served as a lecturer and Associate Professor at Tianjin University where he taught experimental techniques in fluid mechanics, turbulence and computation fluid dynamics. In 1993 and 1994 he was an Alexander Von Humboldt Research Fellow at the prestigious Max-Planck-Institute of Fluid Mechanics in Göttingen, Germany. Holden joined our group in 1998. With his strong background both in modeling and experimental research, Holden has proven himself as an invaluable asset to our team. He currently devotes his time to TUFFP, TUPDP, and the Texaco multiphase metering project. His responsibilities also include day-to-day supervision of research assistants.

TUFFP Financial Status

With the combination of careful monitoring of expenditures, an agreement with the University of Tulsa to not charge any of Dr. Sarica's salary to TUFFP for 2001, sharing of staff expenses with new research contracts, and delays in arrival dates of graduate students, the anticipated reserve fund surplus is expected to be near $280,000 at the end of 2001. On the basis of the excellent financial condition of TUFFP, it will not be necessary to increase membership fees for 2002. Thirteen companies have paid their 2001 membership fees and the three remaining companies will soon be contacted and urged to pay fees as soon as possible.

2001 Questionnaire

The 2001 TUFFP Questionnaire was e-mailed to the official Advisory Board representatives during the second week of August. Members were asked to express their relative interest on existing and possible future research projects. A request was made that the questionnaire be returned by September 15, 2001. Results will be tabulated and summarized in the brochure for the November 15, 2001 Advisory Board Meeting.

Please complete and send in your Request for Information form and make hotel reservations for the upcoming Advisory Board meetings as soon as possible.

2001 Fluid Flow Projects Membership

Arabian Oil Co., Ltd.
Baker Atlas
BG International
BP Exploration
Chevron Petroleum Technology Company
Conoco, Inc.
ECOPETROL/Instituto Colombiano del Petroleo
Japan National Oil Corporation
Marathon Oil Company
Minerals Management Service
PDVSA - Intevep
Pemex
Petronas
Phillips Petroleum Company
Texaco
TotalFinaElf

TUFFP Membership

TUFFP has suffered an unexpected loss of half a member for 2001. Last April, we received an e-mail from Arabian Oil Company (AOC) informing us that they had faxed the University of Tulsa on October 3, 2000 of intent to terminate membership in TUFFP for 2001. As soon as we received the April e-mail, we informed them that we did not receive their fax and that our Letter of Agreement required notification by October 1, 2000 if they planned to terminate membership for 2001. In February 2000, AOC's concession agreement with Saudi Arabia for the Al-Khafji field was terminated and AOC's interest was reduced by 50%, still representing Kuwait in the field operations. This budget reduction resulted in their decision to terminate membership in TUFFP. AOC has now offered to pay half of their 2001 membership fee and TUFFP has agreed to this arrangement. With the pending merger of Chevron and Texaco, we anticipate losing another member for 2002.

We are currently developing a professional prospectus for TUFFP. The prospectus will provide factual information on TUFFP. In addition, a separate general information sheet for every TUFFP test facility will be prepared to better describe their capabilities. The prospectus and information sheets will be used for marketing purposes.

We have initiated communications with past and possible new members in an effort to expand our membership. Discussions are underway with the U.S. Department of Energy, ExxonMobil Upstream Research Company, Saudi Arabian Oil Company, Statoil, Petrobras, Shell Global Solutions, Schlumberger, Halliburton, and Simulation Sciences.

Fall 2001 Advisory Board Meetings

Final plans have now been made for the Fall 2001 Advisory Board meetings. The Tulsa University Paraffin Deposition Projects (TUPDP) Advisory Board meeting will be held on October 4-5, 2001 in New Orleans, Louisiana following the 2001 SPE Annual Technical Conference and Exhibition due to requests from a majority of the member companies. The Severe Slugging JIP Advisory Board meeting will begin at 9:00 a.m. on Wednesday November 14, 2001 at the Adam's Mark Hotel in Tulsa. A tour of test facilities will be held at 3 p.m. Following the tour, there will be a joint Severe Slugging and TUFFP reception at the Adam's Mark Hotel from 6:00 - 9:00 p.m. The TUFFP Advisory Board meeting will be held at the Adam's Mark Hotel and will begin at 8:30 a.m. on Thursday, November 15 and will adjourn at 5:00 p.m.

The Request for Information Form and the Adam's Mark Hotel Reservation form will be placed on the TUFFP web page in mid-September. 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.tuffp.utulsa.edu. You can then follow the links to the Request for Information form. The Hotel Reservation form is a word document for downloading and faxing to the hotel.

Tentative dates and locations for the Spring 2002 Advisory Board meetings have not yet been determined.

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 TUFFP web site at www.tuffp.utulsa.edu 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 27th annual TUFFP Short Course on Two-Phase Flow in Pipes was cancelled due to insufficient enrollment. The TUFFP short course will be offered again in May 2002. Dates will be announced at the next Advisory Board meeting.

SPE Annual Technical Conference and Exhibition

Two papers will be presented by TUFFP researchers at the 2001 SPE Annual Technical Conference and Exhibition. Mr. Ryo Manabe will present a paper titled "Crude-Oil/Natural-Gas Two-Phase Flow Pattern Transition Boundaries at High Pressure Conditions" in the Facilities and Production Operations poster session on Monday October 1, 2001. Dr. Qian Wang will present a paper titled "An Experimental Study on Mechanics of Wax Removal" in the Optimizing Production Transport and Flow Assurance session on Tuesday, October 2, 2001.

BHR Group Conferences on Multiphase Production

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.

The 2001 conference was held in Cannes, France on June 13-15, 2001. Four TUFFP personnel attended the meeting. Mr. Eissa Al-Safran, one of our Research Assistants, presented a paper titled "Prediction of Slug Length Distribution Along a Hilly Terrain Pipeline Using Slug Tracking Model". Over 30 excellent papers and Masterclass problem solving forums were a great success.

The third North American BHR Group Multiphase Technology meeting is scheduled for June 6-7, 2002 in Banff, Canada. Call for Paper Forms are now available from BHR Group. The deadlines for abstract submittal and final manuscript submission are September 28, 2001 and January 18, 2002, respectively. We expect that the meeting will benefit anyone engaged in the application, development and research of Multiphase Technology for the oil and gas industry.

Future Advisory Board Meetings Schedule

October 4, 2001

Tulsa University Paraffin Deposition Projects
Advisory Board Meeting
Pan-American Life Conference Center - New Orleans, LA

Tulsa University Paraffin Deposition Projects
Reception
The Whitney, a Wyndham Historic Hotel -New Orleans, LA

October 5, 2001

Tulsa University Paraffin Deposition Projects
GUI Workshop
Pan-American Life Conference Center - New Orleans, LA

November 14, 2001

Severe Slugging JIP
Advisory Board Meeting
Adam's Mark Hotel - Tulsa, OK

Tulsa University Fluid Flow Projects/Severe Slugging JIP
Tour of Test Facilities
University of Tulsa North Campus - Tulsa, OK

Tulsa University Fluid Flow Projects/Severe Slugging JIP
Reception
Adam's Mark Hotel - Tulsa, OK

November 15, 2001

Tulsa University Fluid Flow Projects (TUFFP)
Advisory Board Meeting
Adam's Mark Hotel - Tulsa, OK

Progress Reports

Two-Phase Flow in Hilly-Terrain Pipelines

Two-phase slug flow in horizontal and near-horizontal pipes is a common occurrence in many engineering applications and industrial operations. Hilly-terrain pipelines consist of interconnected horizontal, uphill and downhill sections. Such configurations can result in terrain-induced slugs that are much longer than those normally encountered in horizontal pipelines, and they often cause operational problems.

Eissa Al-safran

In this study, two-phase flow in hilly-terrain-pipelines is being investigated experimentally and theoretically. The objectives of this project are as follows:

- Investigate slug initiation at the bottom elbow and slug dissipation at the top elbow.
- Develop closure relationships for slug tracking models.
- Generate data to evaluate the developed models.
- Develop a model to simulate two-phase flow in hilly-terrain pipelines.

The test facility used is a 420-m (1378-ft) long, 50.8-mm (2-in.) diameter, horizontal steel pipeline that was recently modified to conduct the preliminary experimental part (phase I) of this study. A new test section made of 2-in. diameter transparent acrylic pipe, simulates a single hilly-terrain unit of 70-ft uphill (downhill) and 70 ft downhill (uphill) sections. The inclination angles are $\pm 1^o$, $\pm 2^o$ from horizontal (valley configuration), horizontal configuration and $\pm 1^o$, $\pm 2^o$ from the horizontal (hill configuration). The test section contains four measurement stations to monitor the change in slug flow characteristics along the test section. A total of 115 tests were conducted with hills and valleys configurations. The superficial liquid and gas velocities ranged from 0.2 to 4 ft/s and from 2 to 15 ft/s, respectively.

A preliminary uncertainty analysis was conducted on the measured parameters in the experiments, such as the temperature, pressure, flow rates and liquid holdup. A preliminary sensitivity analysis was also conducted on the translational velocity and liquid holdup in the slug body using Monte Carlo simulation. It was found that the superficial gas velocity has the most impact on both slug liquid holdup and translational velocity.

The TUFFP slug-tracking model has been validated with the acquired data. Some areas have been identified where improvements are needed for the model to better predict the development of slug flow in hilly-terrain pipelines.

A Comprehensive Mechanistic Heat Transfer Model and High Pressure Flow Pattern Validation for Two-Phase Flow

Ryo Manabe

Estimating heat transfer, including the prediction of convective heat transfer coefficients, for gas-liquid two-phase flow is a main concern in modeling thermal behavior of petroleum multiphase systems. However, the petroleum industry has paid less attention to heat transfer in multiphase flow than to the hydrodynamics, such as flow pattern, pressure drop and liquid holdup. Thus, the heat transfer for crude oil-natural gas two-phase flow is not well understood, and a robust prediction method for all possible operating conditions in petroleum multiphase systems does not exist.

Flow pattern is a central issue in two-phase hydrodynamics. Clearly, two-phase heat transfer also strongly depends on the existing flow pattern. Although existing flow pattern models have been well validated in low-pressure systems, the validity of these models under high-pressure conditions has not been adequately documented in the literature.

The objectives of this project are to:

- acquire experimental data on flow pattern transition boundaries and heat transfer for high pressure gas-liquid (natural gas-crude oil) two-phase flow in horizontal, vertical and inclined pipes,
- verify and extend the mechanistic flow pattern transition models to high pressure conditions,
- develop a comprehensive mechanistic heat transfer model, and
- validate the proposed model with experimental data.

All experimental data acquisition, including both high-pressure flow pattern validation tests and two-phase heat transfer tests, have been completed.

The results of the high-pressure flow pattern validation tests were reported at the TUFFP Advisory Board meeting in November 2000 and will be presented at the SPE ATCE 2001 in New Orleans.

The study on two-phase heat transfer is still underway. The data analysis and model development for vertical two-phase flow were presented at the TUFFP Advisory Board Meeting in May 2001. Currently the study is focused on horizontal two-phase flow. Ryo Manabe is scheduled to complete his PhD work in September 2001. A report (based on Ryo's dissertation) will be distributed to TUFFP members shortly afterwards.

A Unified Mechanistic Model for Gas-Liquid Flow in Wells and Pipelines

During oil and gas production, fluids are transported upwards from vertical or deviated wells, through hilly-terrain pipelines to downstream processing facilities. Steam, water and gas injection are often used to boost production rates. Therefore, gas-liquid two-phase flows at all inclination angles from vertical downward to vertical upward are frequently encountered in the oil and gas industry. A unified model is required which can accurately predict two-phase flow behavior at all inclination angles.

The status of the unified hydrodynamic model was reported at the TUFFP Advisory Board meeting in May 2001. The new

model can be used 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 degrees. The model is based on the dynamics of slug flow, which shares transition boundaries with all the other flow patterns. By use of the entire film zone as the control volume, the momentum exchange between the slug body and the film zone is introduced into the momentum equations for slug flow. The equations of slug flow are used not only to calculate the slug characteristics, but also to predict transitions from slug flow to other flow patterns.

Significant effort has been made to eliminate discontinuities among the closure relationships through careful selection and generalization. The flow pattern classification is also simplified according to the hydrodynamic characteristics of two-phase flow. The new model has been verified with extensive experimental data acquired with different pipe diameters, inclination angles, fluid physical properties, gas-liquid flow rates and flow patterns. Good agreement is observed in every aspect of the two-phase pipe flow.

The final report on the development of the new unified model will be distributed to TUFFP members in August 2001 along with computer programs for prediction of flow pattern transitions and flow behaviors.

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

Qian Wang

Gas-liquid two-phase flow exists extensively in the transportation of hydrocarbon fluids. A more precise prediction of liquid holdup in near-horizontal, wet-gas pipelines is needed in order to better size 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 inner diameter, 19-m long test facility is being used for this study. The test loop can be inclined from -2 degrees to +2 degrees from the horizontal. The fluids used are air and water.

This study was reoriented after the November 2000 TUFFP Advisory Board meeting. According to the comments and expectations from member companies, the present study focuses on very low liquid loading 50-300 m^3/MMm^3. A new turbine meter for water flow rate was installed in the flow loop. With this new flow meter, liquid loadings as low as 50 m^3/MMm^3 (about 10 bbl/MMscf) can be measured. The test facility was then operated to collect data at lower liquid loading.

The flow patterns observed in the very low liquid loading region are mainly stratified smooth and stratified wavy. However, there are some obvious differences in flow behaviors, even with the same stratified flow region. The differences in flow behaviors cause some interesting changes in pressure gradient and liquid holdup.

More experiments will be conducted at different inclination angles. A new model will be developed for prediction of liquid holdup and pressure gradient in wet-gas pipelines. The interfacial friction factor will be evaluated in terms of the interfacial wave structures.

TUFFP Updating Flow Pattern Map Generation Program

The prediction of flow patterns is one of the most important problems in two-phase flow in pipes. During the last 25 years efforts have been directed towards the development of physical or mechanistic models that allow the prediction of transition boundaries between flow patterns in steady-state two-phase flow. With these models, flow pattern transition boundaries for a specific two-phase flow system can be predicted numerically. However, calculation of the flow pattern transition boundaries is a complex and tedious task. It is necessary to develop a computer program to generate the flow pattern map for different fluids and flow conditions.

TUFFP developed its first program for generating flow pattern map in the mid 1980's. This program, FLOPAT, was based on the mechanistic models presented by Taitel & Dukler in 1976 and others. Using this program, the main flow patterns such as dispersed bubble flow, annular flow, stratified flow and intermittent flow can be distinguished. However, different mechanistic models were used in FLOPAT for different inclination angle ranges. As a result, there may be discontinuities in mechanisms as the inclination angle changes.

Based on the progress made in Barnea's (1987) study, a new computer program, FLOPAT II, has been developed. Numerical tests at different inclination angles, pipe diameters and fluid properties have been performed with this program. Compared with FLOPAT, the transition boundaries are improved by using FLOPAT II, especially for the transition between annular and intermittent flows in upward inclinations.

An EXCEL MACRO program was also generated to plot the flow pattern map using the prediction results by FLOPAT II. In the near future, a more convenient GUI will be developed for data input/output and demonstration of the flow pattern map. All the new developments will be posted on the TUFFP website.

BP Flow Loop Status

The 6-in. diameter flow loop donated by BP is now fully operational. The loop was commissioned in November 2000. The large diameter transparent test section is an excellent visualization tool for Petroleum Engineering students and professionals. This facility can be used for testing of instruments or meters, for conventional multiphase flow research projects and is also well suited to assess effects of pipe diameter by comparison with data from smaller diameter pipes.

In early May, two gamma densitometers were tested on the 6-in. flow loop for BP Amoco. The purpose of these tests was to obtain experience in using and troubleshooting gamma densitometers for flow pattern determination and obtaining slug characteristics before conducting more expensive tests offshore. The calibration, setup and processing of the data are essential for this use of gamma densitometers. Operators unfamiliar with these tasks can benefit greatly from flow loop training before proceeding to field tests. This is one possible academic and practical objective of this easy to operate multiphase flow loop. Additional tests are planned for BP in October.

Paraffin Deposition Projects (TUPDP)

Deposition Flow Loops

After upgrades and repairs, both the single-phase flow loop and high-pressure multiphase flow loop are now operational and the extensive testing campaign will be continued.

Additional deposition tests with the 33 API crude oil are now complete. These tests are now being processed and samples will be analyzed. These tests should refine our deposition model, especially for the prediction of the oil content of the deposit, in the transition region.

Tests to come include further testing of the condensate started in the previous JIP, under single-phase and multiphase flow conditions. A third oil, in the 20's API range, will also be tested at TU. Valuable information will then be collected on the sensitivity of the deposition phenomena to different oils and different oil properties. With the extensive testing undertaken with each of these crude oils, TUPDP will develop a large database of test results, counting already 50 tests and expanding to about 100 tests by the end of this 3-year period.

Future Plans

Modifications of the multiphase flow loop to accommodate a water phase will start at the end of this year, in order to generate three-phase deposition data. Finally, an existing flow loop is being modified to expand testing capabilities into smaller diameters. The purpose of this smaller flow loop will be to generate quicker deposits to perform pre-screenings of tests to be run in the larger flow loops.

Analytical Capabilities

Over the past 6 months, TUPDP has increased its analytical measurements capabilities. A power-compensation differential scanning calorimeter (DSC) has been purchased. This DSC, a Perkin-Elmer Pyris 1, will permit wax melting point measurements, oil wax appearance temperature measurement and solid fractions measurements, key parameters in the investigation of wax deposition.

Perkin-Elmer Pyris 1

In addition, a pigging skid has been developed and will be used to measure the shear force required to pig the wax deposited during our experiments. This measurement will be a continuation of Deepstar studies conducted at Penn State University on the mechanisms of wax removal.

Pigging Device

Finally, a videoscope - a CCD mounted on a 20-ft flexible cable - has been purchased. This device, typically used to inspect vessels and pipes for blockages or corrosion, expands TUPDP's capabilities in visually documenting test results and provides additional measurements of wax deposit thickness and possibly roughness. Enhanced quality pictures provide information on the wax structure and other phenomena, such as shear stripping or sloughing of the deposits.

Modeling

The wax deposition simulation code will be modified this year to include the film mass transfer model in addition to the diffusion model. These two models express the same physical phenomenon with two different approaches, but more tests and simulations are required to determine under which conditions one model prevails over the other.

The Singh model, which predicts the aging of the wax deposits with time, will also be implemented and tested versus long-term deposition data (up to 21 days) generated in our flow loops.

Severe Slugging JIP

Severe slugging elimination or slug flow suppression has been one of the emerging flow assurance problems for deep-water developments. Upon successfully completing a proof of concept study on a self-lifting concept, a Joint Industry Project titled "Severe Slugging Elimination in Ultra-Deep Water Tie-backs and Risers" has been formed to conduct a detailed analysis of the concept through further thorough experimental and modeling studies. Current JIP members are Chevron, Marathon, MMS, and TotalFinaElf (Norway). Several other companies are in the process of evaluating the JIP proposal. We are very optimistic that the total number of participants will exceed four. If more funding becomes available through additional members, JIP participants will decide on the expansion of the JIP scope. There have been several suggestions from members and potential participants on how to expand the scope of the project, including the investigation of the occurrence of severe slugging for up-sloping pipeline-riser systems and testing of other suppression methods.

Currently, an existing TUFFP test facility is being modified for this project. The modified test facility will consist of a 65-ft long pipeline followed by a 40-ft riser using a 3-in. ID. acrylic pipe. The pipeline can be expanded to simulate 280 ft by using variable volume tanks. The pipeline inclination angles to be investigated are ranging from -1° to -5°, with increments of 1°. The experimental facility is expected to be operational in August. Preliminary test results will be presented at the next JIP Advisory Board meeting on November 14, 2001.

Texaco Metering

The University of Tulsa has recently been contracted by Texaco Upstream Technology Company to perform a modeling study on their steam metering technology. Drs. Zhang, Wang and Sarica will be involved in this study. The project duration is expected to be one year.

Over the years, Texaco has developed a steam metering technology based on the measurement of differential pressure, dp, fluctuations across an orifice. It was realized that empirical

correlations and the Neural Network models performed very well within their development range. Unfortunately, the results were quite poor for operating conditions beyond their development range. There has been little effort made towards the understanding of the physical phenomenon of two-phase flow through an orifice from a mechanistic modeling point of view. The main objective of this study is to investigate and develop a mechanistic model that can be applicable without range concerns. The expected outcome is the steam quality and mass rate estimates without calibration for different pipe diameters.

New Initiatives

TU Organizing New Hydrate JIP

In January, TU received a Request for Proposal from Marathon Oil Company to transfer their new Flow Assurance Loop (FAL) from Littleton, Colorado for the purpose of conducting flow assurance research. The FAL was constructed in 1999 and Marathon made a decision to terminate its flow assurance research program in late 2000.

Marathon's Flow Assurance Loop in Littleton, Colorado

The FAL has the following characteristics: 2200 psia working pressure; 2.9-in. ID; 162-ft long; 20 tons chilling; Leistritz multiphase pump with circulating rate yielding flow velocity of 15 ft/s; 4 sapphire, 1.5-in. diameter viewing ports; pressure, temperature and density instrumentation; substructure that permits angle changes and rocking motion.

A proposal was submitted to Marathon by Mike Volk and Jim Brill in late January and in early June we were notified that Marathon intended to donate the FAL to TU, subject to various terms and conditions. A Letter of Agreement was negotiated with Marathon in late July. Current plans are to examine and observe the operation of the FAL in mid August, and hold a hydrate workshop in Houston shortly thereafter with attendees being potential JIP members. The purpose of the workshop is to seek industry input on identifying and prioritizing the most important flow related research topics pertinent to hydrate operating problems. A prospectus to form the JIP will then be prepared and mailed worldwide to all potential participants. Attempts will also be made to pursue significant collaboration with Dr. Dendy Sloan at the Colorado School of Mines.

An ambitious goal would be to start the JIP on January 1, 2002 and simultaneously begin to dismantle and ship the FAL to TU's North Campus. Site preparation at TU would also begin at that time and approximately 9 months would be required to reassemble the FAL in Tulsa. We envision establishing a 4-year JIP with a total participating fee of $160,000. from each member. Significant support will also be solicited from the U.S. Department of Energy.

Calendar of Events

2001

August 5 – 10	SPE Forum Series in North America III – Subsea Well Design and Intervention, Park City, Utah, USA
September 30 - October 3	2001 SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana
October 4	Tulsa University Paraffin Deposition Projects (TUPDP) Advisory Board Meeting - New Orleans, Louisiana
October 5	Tulsa University Paraffin Deposition Projects (TUPDP) GUI Workshop - New Orleans, Louisiana
November 14	Severe Slugging JIP Advisory Board Meeting - Tulsa, Oklahoma
	Tulsa University Fluid Flow Projects (TUFFP) Tour, Joint TUFFP/Severe Slugging Reception
November 15	Tulsa University Fluid Flow Projects (TUFFP) Advisory Board Meeting - Tulsa, Oklahoma

2002

February 4 - 6	ETCE 2002 – Houston, Texas
March 10 - 14	AIChE Spring National Meeting - New Orleans, Louisiana
May 6 - 9	Offshore Technology Conference - Houston, Texas
June 6 - 7	BHR Group Conference on Multiphase Production – Banff Springs, Alberta, Canada