THE UNIVERSITY of TULSA

TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

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Editorial by Cem Sarica

As I mentioned in my editorial in the Summer 2001 Newsletter, our industry is continuing to go through a significant transformation due to mergers and buyouts. Recently, we learned about the announced merger of Conoco and Phillips. These changes have a direct impact on TUFFP and pose a challenge for us to continue as an "Institution" in Multiphase Flow and Flow Assurance Technology Development, Education, and Training.

On the other hand, the challenges that our industry faces in multiphase flow production and flow assurance areas are increasing as more fields in ultra-deep waters and harsh environments are targeted. Therefore, it is expected that there will be a greater need for the development of newer technologies for years to come. Our objective is to continue as one of the technology development incubators for our industry, addressing both short-term and long-term needs.

A new project management structure for TUFFP projects has been proposed to significantly increase the interaction between TUFFP and the member company representatives. A Technical Advisory Committee (TAC) consisting of TUFFP member representatives is expected to participate in every aspect of the projects from initiation to completion. Initial discussions on this proposal were held at the November 15, 2001 Advisory Board meeting. A summary of the discussions and a solicitation of more input from members have been sent to member company representatives. A TAC kickoff meeting was held on February 6, 2002.

Technology transfer is one of the priorities of TUFFP. There is a tremendous amount of accumulated knowledge, experimental data, models and reports from previous TUFFP research projects. Our objective is to make all deliverables available through the TUFFP WEB page.

I am happy to announce that since the last Advisory Board meeting we have added three new M.S. students to our family. One will be assigned to a TUFFP project. The other two will be assigned to projects within the Tulsa University Paraffin Deposition Projects.

TUFFP activities are summarized later within 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 has now been completed. The final report, along with the computer program, have been posted in the "Members Only" section of the TUFFP web page. Flow pattern generation programs, FLOWPAT II and III with a simple GUI are now available for downloading from the TUFFP web page. Ryo Manabe has completed the development of a mechanistic model to predict multiphase flow local heat transfer phenomena for different flow patterns in wells and pipelines. Eissa Al-Safran continues to analyze his data. Some of the data implies that initiated slugs can travel at a lower velocity than the mixture velocity. He is aiming at developing closure relationships to be used in a slug-tracking program. The low liquid loading gas-liquid flow in near-horizontal pipes project continues with experimental tests for different inclination angles. Simultaneously, Dr. Holden Zhang is developing a unified model for spatially developing gas-liquid pipe flow (including slug tracking). Eissa's and Holden's studies, along with Tel-Aviv studies completed earlier, will complement each other. Mr. Yongqian (Richard) Fan has been assigned to this project. Oil-water-gas flow research that has consistently received high rankings over several years in our questionnaires has been initiated with two parallel projects. Our ultimate goal is to develop a comprehensive mechanistic model for gas-oil-water flow in pipes. Mr. Mohammed El-Rebdi will assess the three-phase flow technology, identify the gaps and weaknesses in our models, and develop a

preliminary model. Mr. Cengizhan Keskin has started with his facility design and modifications to the TUFFP oil-water flow facility to experimentally investigate gas-oil-water flow in horizontal and slightly inclined pipes. Initially, the emphasis will be on the investigation of flow patterns.

The long term plans for utilization of the BP 6 in. I.D. flow loop are currently underway. Initially, the low liquid-loading studies will be continued using the BP flow loop to investigate the diameter effects using air and water. A feasibility study is being conducted to convert the facility to a Sulphur Hexaflouride (SF6), oil, and water closed flow loop. The use of SF6 will enable us to investigate pressure effects without operating under high-pressure conditions.

Our efforts to form the Hydrate JIP have begun to bear fruit. Currently, approximately 11 companies have indicated that they will participate in the JIP. Several companies are still evaluating the proposal. The first phase of the severe slugging JIP will be completed in August 2002. A questionnaire has been sent to interested parties for a possible second phase.

New Research Assistants Arrive

Mohammed Al-Rebdi

We are pleased to announce the addition of three new MS students to our projects. Mr. Mohammed Al-Rebdi from Saudi Arabia has received his B.S. degree in Chemical Engineering from The University of Tulsa With a GPA of 4.0 in 1998. He worked for Saudi Aramco for 3 years in production operations. Mohammed has been sent to TU to pursue a Master's degree in petroleum engineering. He has been assigned a TUFFP research project on gas-oil-water flows.

Jose Alana

Mr. Jose Alana, from Venezuela received his BS degree in Mechanical Engineering in 2000 from the Universidad Simon Bolivar. Jose has worked part time at TUPDP helping Oris Hernandes in the Fall 2001. He has been awarded a research assistantship with TUPDP based on his excellent performance. He will be continuing single-phase paraffin deposition studies.

Mr. Guilherme Cuoto from Brasil received his BS in Mechanical Engineering in 1998 from Pontificia Universidade Catolica do Rio de Janeiro. Guilherme will be supported by TUPDP. Guilherme will be studying the effects of a water phase on paraffin deposition.

2002 Fluid Flow Projects Membership

Baker Atlas
BG International
BP Exploration
Chevron Petroleum Technology Company
Conoco, Inc.
Japan National Oil Corporation
Marathon Oil Company
Minerals Management Service
PDVSA - Intevep
Pemex
Petronas
Phillips Petroleum Company

TUFFP Financial Status

TUFFP's financial status remains stable despite the fact that we have lost 3 members for 2002. We entered 2002 with $301,887 in our reserve fund. Our 2002 income will be $420,000 for 12 members. Our estimated total expenditures for 2002 are $520,000. This includes major modifications for the 6-in. BP flow loop and the gas-oil-water facility. The imbalance between the income and 2002 expenditures will be compensated from the reserve account, lowering the balance to approximately $200,000 at the end of 2002.

TUFFP Membership

Ecopetrol, Texaco and TotalFinalElf have terminated their TUFFP membership for 2002. We have had very positive meetings with Saudi Arabian Oil Company, Schlumberger, and Simulation Sciences to rejoin TUFFP. We are also discussing with the U.S. Department of Energy for their possible support to leverage industry funding. Discussions are also underway with ExxonMobil, Halliburton, Petrobas, Pertamina, Shell, and TotalFinalElf.

A professional prospectus providing factual information on TUFFP has been prepared and made available to the general public through the TUFFP web page in the About TUFFP section. The prospectus is intended for marketing purposes.

New Computer Manager

Jose Aramburu

Dan Underwood recently accepted a position with Williams Companies in Tulsa and we have hired José Manuel Aramburú Tinoco to fill this vacated position.

José first became familiar with the University of Tulsa through the Newman Center. He volunteered through his church to help out at the Tuesday luncheons. José began his freshman year in 1997 as a Computer Information Systems major. He will receive his BS degree this December but he is researching the possibility of further exploring different areas that have captured his interest, like Environmental Engineering.

He feels his position with TUFFP/TUPDP will give him the opportunity to practice the skills he is learning in Systems Administration.

Technical Advisory Committee Kicks Off

The first meeting of the Technical Advisory Committee (TAC) was held in Tulsa, Oklahoma on February 6, 2002. The industry participants of the meeting were Norm McMullen of BP, Gene Kouba of ChevronTexaco, Tom Danielson of Conoco, Rob Sutton of Marathon, and Harvey Hensley of Phillips. During this meeting, TUFFP research activities were discussed. Interaction between the TUFFP staff (students and Research Associates) and the TAC was very productive for the on-going TUFFP research projects. We would like to see an even larger membership participation in the TAC activities.

The minutes of this kickoff meeting will soon be sent to TUFFP members. The highlight of the meeting was the discussion on deliverables. Three different categories of deliverables were identified. The first category, short-term projects, is the preparation of existing data and software for easy use by members companies. Examples of this category would be FLOPAT2 and FLOPAT3. The second category deals with medium-term projects that have a 1 - 2 year maximum duration. These projects are expected to produce results that will have an immediate impact on the petroleum industry. Member companies will be asked to prepare a small one-paragraph description of these projects. Project descriptions will then be rated by the entire TUFFP membership. The projects that have a common interest of the members can be initiated based on the availability of resources. The third category is the long-term projects such as Gas-Oil-Water Flow and High Pressure - Large Diameter Pipe studies. The TAC has also emphasized the importance of intermediate deliverables of long-term projects.

The TAC has recommended that a knowledge map of multiphase flows be prepared to identify technology gaps, and direct the TUFFP resources to fill those gaps.

Web Page Improvements

Over the few months, there have been several major modifications to the TUFFP web page. The “About TUFFP” section has been totally revamped. There is a short description of TUFFP, our funding, membership fees, Current Membership, Scope of Work, Major Deliverables, Accomplishments, Project Selection Process, Current Projects, Future Projects and Deliverables. The “Facilities” section has also undergone some major changes with more changes anticipated in the near future. In this section, you will find a description of all facilities that TUFFP has access to. We have also included several photographs of the facilities. In the near future, we plan on adding operating conditions of the facilities. In the “Research” section, the current projects have been updated and we have added future projects. “Staff” pages have been updated. In the “Calendars” section, there is now a Calendar of Events and an Academic Calendar. The “Members Only” section has also had significant modifications. There are now sections for: Reports, Experimental Data, Software, TAC Activities, Publications/Presentations and TUFFP/TUPDP Standards. In the Report section, the reports have now been categorized by subject. We are also in the process of scanning old reports and uploading them on the web.

As always, we are open to suggestions on items that the member companies would like to see. Please email your suggestions to Cem Sarica at sarica@utulsa.edu or to Linda Jones at jones@utulsa.edu

Meetings and Conferences

TUFFP Short Course

The 28th annual TUFFP Short Course on Two-Phase Flow in Pipes will be taught May 13 - 17, 2002 at the Tulsa Marriot Southern Hills Hotel. Dr. Sarica and Dr. Brill will be teaching the course.

A major change in the 2002 course will be to replace the module on Inflow Performance Relationship with one on paraffin deposition. This will include material on fluid characterization, deposition models, effect of turbulence, wall shear and flow pattern, and a software demonstration using TUWAX, the multiphase paraffin deposition program available to members of both the previous Wax JIP and the new Paraffin Deposition Consortium (TUPDP) at The University of Tulsa.

The registration fee schedule for the short course is given below:

TUFFP and TUPDP Member Companies		**Non-Member Companies**	
Per Person	$1,200	Per Person	$1,895
Group Discount - Per Person	$1,100	Group Discount - Per Person	$1,695

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.tuffp.utulsa.edu in the Calendars section. Interested persons are urged to enroll as soon as possible to help us plan the course.

Spring 2002 Advisory Board Meetings

Final plans have now been made for the Spring 2002 Advisory Board meetings. All meetings will be held at the Doubletree Hotel at Warren Place in Tulsa, Oklahoma. The meetings will be held in the Monterey Room with lunches in the Orange Room. The Severe Slugging JIP Advisory Board meeting will begin at 9:00 a.m. on Monday April 22, 2002. A tour of test facilities on the North Campus will be held at 3 p.m. Following the tour, there will be a joint Severe Slugging, TUFFP, and TUPDP BBQ between 5:00 - 7:00 p.m. The TUFFP Advisory Board meeting will begin at 8:30 a.m. on Tuesday, April 23 and will adjourn at 5:00 p.m. Following the meeting, there will be a joint Severe Slugging, TUFFP, and TUPDP reception from 6:00 - 9:00 p.m. in Ballroom D of Warren Place II. On Wednesday, April 24, 2002, the TUPDP Advisory Board meeting will be held. The meeting will start at 8:00 a.m. and will adjourn at 5:00 p.m.

The request for information form and the Doubletree Hotel at Warren Place Information form will be placed on the TUFFP web page in early March. 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 in the “ABM Info” section. You can then follow the links for the request for information form and hotel reservation form. Both forms will be added as a word document and as a pdf file.

Tentative dates and locations for the Fall 2002 Advisory Board meeting 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 in the “ABM Info” section 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.

Future Advisory Board Meetings Schedule

April 22, 2002

Severe Slugging JIP
Advisory Board Meeting
Doubletree Hotel at Warren Place - Tulsa, OK

Severe Slugging JIP/TUFFP/TUPDP
Tour of Test Facilities
University of Tulsa North Campus - Tulsa, OK

Severe Slugging JIP/TUFFP/TUPDP
Barbeque
University of Tulsa North Campus - Tulsa, OK

April 23, 2002

Tulsa University Fluid Flow Projects (TUFFP)
Advisory Board Meeting
Doubeltree Hotel at Warren Place - Tulsa, OK

Severe Slugging JIP/TUFFP/TUPDP
Reception
Warren Place II - Tulsa, OK

April 24, 2002

Tulsa University Paraffin Deposition Projects (TUPDP)
Advisory Board Meeting
Doubletree Hotel at Warren Place - Tulsa, OK

BHR Group Conferences on Multiphase Production

Since 1991, TUFFP has participated as a co-sponsor of the BHR Group Conferences on Multiphase Production. TUFFP personnel participate in reviewing papers, serving as session chairs, and advertising the conference to our members. The third North American BHR Group Multiphase Technology meeting is scheduled for June 6 - 7, 2002 in Banff, Canada. Over 30 papers are scheduled to be presented. The meeting will benefit anyone engaged in the application, development and research of Multiphase Technology for the oil and gas industry.

2002 ETCE Meeting

The Production Technology Symposium at ETCE 2001 was held February 4 - 5, 2002 at the Sheraton North Houston Hotel. A total of 20 papers were presented in 7 technical sessions. Most of the papers were of excellent quality and attendance was modest. Mr. Eissa Al-Safran and Dr. Holden Zhang presented papers on TUFFP research.

TUFFP Graduate Seminars

We are resurrecting the TUFFP graduate seminars. The purpose of the seminars is to increase the interaction and synergy between fellow researchers, not only within the TUFFP and TUPDP groups, but also within the Petroleum Engineering Department in multiphase flow subjects. The seminars will also significantly contribute to students' graduate education by exposing them to subjects other than their own research projects. All seminars will be held at 3:30 p.m. in the Paraffin Deposition Conference Room on the North Campus. A list of Spring 2002 seminars is given below and have also been posted on the TUFFP web page. We encourage the participation of TUFFP members in the graduate seminars by being guest speakers or simply attending the seminars.

March 1, 2002 - Multiphase Flow Modeling - Holden Zhang
April 5, 2002 - TUFFP Experimental Facilities and Instrumentation - Tony Butler
April 26, 2002 - Computation Issues in Engineering Calculations - Leslie Thompson

Progress Reports

Two-Phase Flow in Hilly-Terrain Pipelines

In this study, two-phase flow in hilly-terrain pipelines is being investigated experimentally and theoretically. The experimental program is a major part of this project. A test section made of 2-in. diameter transparent acrylic pipe was used to simulate a single hilly-terrain unit of 70-ft uphill (downhill) and 70 ft downhill (uphill) sections. The inclination angles were $\pm 1°$, $\pm 2°$ from horizontal (valley configuration), horizontal configuration and $\pm 1°$, $\pm 2°$ from the horizontal (hill configuration). The test section included four measurement stations to monitor the change in slug flow characteristics along the test section. A total of 105 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 two-phase flow mechanistic model to predict slug initiation at the bottom elbow and slug length distribution at the hilly terrain pipeline entrance is one of the tasks of this project. Furthermore, closure relationships will be developed to improve the slug dissipation and growth in the downhill section and uphill section, respectively. The film hydrodynamics will be studied carefully because of its crucial role in the above-mentioned mechanisms. These models and closure relationships will be eventually integrated into the TUFFP slug-tracking model to improve its predictions.

After completing data processing and data uncertainty analysis, currently the emphasis is placed on the data analysis and modeling. The TUFFP slug-tracking model will be validated with the experimental data and will be compared with the OLGA slug-tracking model. A detailed progress report will be presented at the next Advisory Board meeting in April 2002.

Gas-Oil-Water Pipe Flow

Three-phase gas-oil-water flow is a common occurrence in the petroleum industry. However, there is only a limited amount of knowledge and published work on the subject. The ultimate goal of TUFFP for gas-oil-water studies is to develop a mechanistic model based on theoretical analysis and experimental results. Two initial studies of gas-liquid-water flow have been initiated. One of the studies aims to thoroughly assess the three-phase flow technology, identify the gaps and weaknesses, and develop a modeling framework. This study has been assigned to Mr. Mohammed Al-Rebdi. The other study will initially focus on the experimental analysis of gas-oil-water flow in horizontal and slightly inclined pipes, starting with the investigation of flow patterns. This study has been assigned to Mr. Cengizhan Keskin.

The assessment study will focus on the applicability of existing gas-oil two-phase flow models for gas-oil-water three-phase flows using the available field and laboratory data. Moreover, a preliminary three-phase flow model will be developed. Model development will start with the derivation of the continuity and momentum equations for the three fluids.

TUFFP's existing oil-water flow facility will be used in the experimental study. 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. Since it is a facility designed for only oil-water flow, modifications are needed to both the flow loop and the test section to perform three-phase flow experiments. A gas metering line will be constructed. New Micro-Motion mass flow meters have recently been purchased for the measurement of air flow rate. The existing test section will be modified by designing and building a new mixing tee, and by adding proper instrumentation. Efforts are underway to identify the instrumentation for the test section.

The literature review is currently underway. Testing is expected to begin before the Fall 2002 Advisory Board Meeting.

Unified Model for Spatially Developing Gas-Liquid Pipe Flows (Including Slug Tracking)

Hilly-terrain pipelines and deviated wells consist of interconnected pipe sections of different inclination angles. Multiphase flow can experience transition from one state to another as pipe inclination angle changes. Normally, slugs dissipate if the upward inclination becomes smaller or the downward inclination becomes larger, and slug generation occurs vice versa. As a result, flow pattern transition may occur between stratified (annular) and slug flows. It may take a certain distance for the flow to be fully developed, and the flow cannot reach a fully developed state if the pipe section with the same inclination angle is too short. Appropriate prediction of multiphase flow behavior is crucial for the design of pipeline and downstream facilities. In this study, a unified model is being developed for spatially developing gas-liquid pipe flow based on the unsteady (transient) continuity and momentum equations for slug and stratified (or annular) flows. The model can be used to simulate the transitions in spatial development between different flow patterns, and to predict slug dissipation and generation in slug flows.

The "Slug Tracking in Hilly-Terrain Pipelines" project was initiated to investigate the formation, development and movement of slugs in hilly-terrain pipelines. It was being conducted in collaboration with Tel-Aviv University but was suspended due to cost cutting requirements. Experimental results from previous and current TUFFP projects, especially the "Two Phase Flow in Hilly-Terrain Pipelines" project will be used for model verification and development of closure relationships.

The new unified model for spatially developing gas-liquid pipe flows can be used to predict slug flow development in hilly-terrain pipelines. In conjunction with the experimental study of hilly terrain two-phase pipe flow, a comprehensive mechanistic model will be developed for slug tracking in hilly-terrain pipelines.

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

TUFFP has developed different comprehensive mechanistic models in the past (Ansari model for upward vertical flow, Xiao model for near-horizontal flow, and Kaya model for deviated wells). However, there are gaps between these models that must be filled to create a unified model. The major difficulty in development of a unified model is the closure relationships for the momentum equations. These relationships must behave smoothly for inclination angles from -90° to 90°. Another problem in previous comprehensive mechanistic models is the separation between flow pattern transition models and models for hydrodynamic behaviors.

This project was initiated in July 2000. A unified hydrodynamic model has been 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°. The model is based on the dynamics of slug flow, which shares transition boundaries with all the other flow patterns. By using 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.

Through careful selection and generalization, significant effort has been expended to eliminate discontinuities among the closure relationships. The flow pattern classification is also simplified according to the hydrodynamic characteristics of two-phase flow. The new model has been validated with extensive experimental data acquired for 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 model predictions will be further compared with measured data in the TUFFP well and pipeline data banks. Currently, the TUFFP pipeline databank is being expanded.

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

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

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° to +2° from the horizontal. The fluids used for this study are air and water. The measured parameters include gas flow rate, liquid flow rate, pressure, differential pressure, temperature, liquid holdup, liquid film flow rate, droplet entrainment fraction and droplet deposition rate. The pressure drop measurement has recently been improved.

Experiments are currently underway. Repeatability tests for -1° and -2° inclination angles are being conducted. The results will be compared with previous tests, and reported at the next Advisory Board meeting.

After the completion of repeatability tests, tests for 0°, 1° and 2° inclination angles will be conducted. In these tests, the liquid loading will range between 50-1800 m^3/MMm^3, and the superficial gas velocity range will be varied between 5-25 m/s.

For upward flow with this low liquid loading range, the mechanistic model has a region in which three solutions exist for the height of the interface or liquid holdup in stratified flow. The multiple solution region for liquid holdup will be carefully examined. The new test data will be used to verify the stable solution in the multiple solution region.

Mechanistic Modeling of Multiphase Heat Transfer in Wells and Pipelines

Estimating heat transfer, including 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 hydrodynamics, such as prediction of 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.

The objectives of this project are: to acquire experimental data on average convective heat transfer coefficients for high-pressure, gas-liquid (natural gas-crude oil) two-phase flow in horizontal, inclined and vertical pipes; to develop a comprehensive mechanistic heat transfer model; and, to validate the proposed model with experimental data.

For his PhD dissertation research, Ryo Manabe developed a comprehensive mechanistic model for heat transfer in gas-liquid pipe flow. The model overall performance is better than previous correlations compared with experimental results.

However, there is room for further improvements. Multiphase heat transfer is closely related to multiphase hydrodynamics. Recently, a new unified hydrodynamic model has been developed at TUFFP that performs better than previous mechanistic models in predicting flow pattern transitions and hydrodynamic flow behaviors. The multiphase heat transfer model can be improved by use of this unified hydrodynamic model. Experimental data also need to be carefully examined and processed in comparison with model predictions.

Flow Pattern Map Generation Program and GUI

Based on recent progress made in developing comprehensive physical models, a new computer program, FLOPAT2, has been developed at TUFFP. FLOPAT2 uses the unified model presented by Barnea in 1987. In this program, the inclination angle is entered as a parameter to calculate the transition boundaries, and the physical models remain the same.

Another new flow pattern generation program, FLOPAT3, has also been developed, which is based on the new unified model developed by Zhang (2001) at TUFFP. In this program, the flow patterns are simplified as bubble, intermittent and stratified/annular flows.

A simple GUI has been developed for using FLOPAT2 and FLOPAT3. With the GUI, the user can input fluid physical properties and pipe geometries, and select either the Barnea or the Zhang unified model. After the calculation, the flow pattern map is generated automatically.

The flow pattern map generation software is now available on the TUFFP web site www.tuffp.utulsa.edu.

BP 6-in. Flow Loop Status

The 6-in. diameter flow loop donated by BP was commissioned in May 2001. 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 and for conventional multiphase flow research projects. It is also well suited to assess effects of pipe diameter by comparison with data from smaller diameter pipes.

In May 2001, two gamma densitometers were tested on the 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. In October 2001 BP returned for final tests of the software for tracking and characterizing slugs. We were able to obtain flow rates, pressure and temperature data as well as the densitometer data.

The low-liquid loading study is planned to be continued in this facility to investigate diameter effects. Moreover, plans are underway to adapt this facility to simulate high-pressure flow conditions by changing the gas phase from air to Sulphur Hexaflouride (SF6). SF6 is a gas with a density about 5 times greater than air.

After the November 2001 Advisory Board Meeting the facility was winterized by draining the tank and removing water from the pump and instrument lines. The system will be re-commissioned in the Spring.

Related Projects

Severe Slugging JIP

Severe slugging elimination or slug flow suppression has been one of the emerging flow assurance problems for deepwater 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" was 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).

An existing TUFFP test facility is being used for this project. The test facility was modified in August 2001. It consists 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. Three pipeline angles will be investigated, -1°, -3°, and -5°. Testing of -1° and -5° was finished in December 2001, and testing of the last inclination angle is expected to be completed in April 2002. Currently the data for -1° and -5° are being processed and modeling efforts are underway. The results of all data acquired and model developments will be presented at the next Advisory Board meeting being held April 22, 2002.

There have been several ideas proposed by current and potential participants to continue the JIP beyond August 2002. A questionnaire has been sent to interested parties, and several responses have been received. The testing of several elimination techniques appears to be a common interest among the interested parties.

Paraffin Deposition Projects

Deposition Studies

No significant changes have been made on the single phase or multiphase flow loops as both flow loops are now operational. A new spool piece, equipped with coupon samplers, was built and installed on the multiphase facility. This new spool piece will allow us to take wax samples during high-pressure multiphase flow tests in order to study the aging process of the deposit. The design of the water phase addition for the multiphase flow loop continues.

The design of the small-scale loop was completed. This facility will mainly be used to investigate the aging phenomena. The main equipment from an existing TUFFP heavy oil-water facility will be reutilized in order to lower the cost. This new facility will be equipped with three 8-ft long test sections of different diameters: ½", 1" and 1-½". Each test section is adequate for a given flow rate range up to 1,200 BPD.

Instrumentation includes oil and glycol temperature transmitters and pressure drop transmitters to monitor the wax buildup. Three sampling ports on each test section will allow us to take samples at determined times during tests. A pig launcher and receiver will allow us to pig the largest test section in the same manner used in the field while monitoring pressure drops across the pig during the pigging operation. All parameters will be recorded with a Labview-based data acquisition and control system.

Several tests were completed with the Garden Banks fluid during the last quarter of 2001 in both single-phase and multiphase flow loops. On the single-phase flow loop, 5 tests were conducted under turbulent flow conditions to study the effect of DT and flow regime on the paraffin deposition process for Garden Banks condensate.

Shear stripping tests were also conducted on the single-phase flow loop in which the oil was flowed at a constant flow rate at a constant temperature difference for 24 hours. After flowing for 24 hours, the oil temperature was lowered to the glycol temperature to avoid further deposition. These conditions were maintained for another 24-hour period. The data gathered from this test shows a constant decrease in the pressure drop readings during the "isothermal" period. The decrease in pressure drop can be attributed to various phenomena, including shear stripping and aging. This test was repeated in January.

After completion of these tests, tests with CBI (Cote Blanch Island) stock tank oil will begin. CBI oil has characteristics similar to South Pelto oil but with a higher viscosity. The fourth fluid to be obtained is for the model validation work. Potential candidates are Troika and/or Pompano fluids from Marathon, Blake from BG International, and Caratinga and/or a fluid from the Albacora field in the Campos basin of Brazil from Petrobras. Discussions are ongoing with these three companies regarding the amount of deposition data they have for their respective fluids, their willingness to share this data, as well as the production history.

Modeling Studies

Several modifications have been made to the single-phase paraffin deposition prediction model. One modification is the segmentation of the pipe. The convective mass transfer model was incorporated into the computer program. The user can select either the molecular diffusion or convective mass transfer, or a "hybrid" between both models for the deposition process. The Singh et al. model is still under review, and will probably be added to the software in the future. Another modification made for the single-phase model is the addition of the shear stripping term. Until we improve our prediction of this phenomenon, the user can arbitrarily set a percentage of what has been deposited as shear stripping.

In the multiphase wax deposition model, the molecular diffusion method for mass transfer was replaced with the convective mass transfer approach. Moreover, the newly developed unified hydrodynamic model for gas-liquid pipe flow has been incorporated into the multiphase wax deposition model.

The new comprehensive two-phase heat transfer model developed by Ryo Manabe was shown to predict the convective two-phase heat transfer coefficient better than OSU recommended correlations. The computer program for the two-phase heat transfer model will be incorporated into the wax deposition software.

Calendar of Events

2002

March 10 - 14	AIChE Spring National Meeting - New Orleans, Louisiana
April 22	Severe Slugging JIP Advisory Board Meeting - Doubletree Hotel at Warren Place - Tulsa, Oklahoma
April 23	Fluid Flow Projects Advisory Board Meeting - Doubletree Hotel at Warren Place - Tulsa, Oklahoma
April 24	Paraffin Deposition Projects Advisory Board Meeting - Doubletree Hotel at Warren Place - Tulsa, Oklahoma
May 6 - 9	Offshore Technology Conference - Houston, Texas
May 13 - 17	Fluid Flow Projects Two-Phase Flow in Pipes Short Course - Tulsa Marriott Southern Hills - Tulsa, Oklahoma
June 6 - 7	BHR Group Conference on Multiphase Production – Banff Springs, Alberta, Canada
September 29 - October 2	SPE Annual Technical Conference and Exhibition - San Antonio, Texas