TUFFP

THE UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

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Cliff Redus taking care of business!

TUFFP Welcomes Dr. Cliff Redus

On July, 1, 1999, Dr. Cliff Redus assumed the Directorship of the Tulsa University Fluid Flow Projects (TUFFP) consortium from Dr. James Brill who will continue involvement with the research program as Director Emeritus. Dr. Redus will be joining the Petroleum Engineering Department for the fall term as an Associate Professor.

In 1976 Dr. Redus received a B.Sc. in Mechanical Engineering from Texas A&M University in Kingsville, Texas. In 1980, and 1985, he received his M.Sc. and Ph.D. degrees respectively, from the University of Houston, both in Mechanical Engineering. Dr. Redus has worked the last 21 years in the petroleum industry, both in industrial research and field operations in the area of multiphase flow. His primary areas of interest are multiphase flow in well bores, flow lines and production equipment, computational fluid mechanics, advanced separation technology and paraffin and hydrate deposition in production flow lines and wells. He was in a supervisory capacity in production related industrial research for the last 10 years with Texaco's Exploration and Production Technology Department in Houston Texas, with the last 4 years as Director of Texaco's live oil multiphase flow loop in Humble, Texas.

Maintaining TUFFP as the preferred research partner for both fundamental and applied research in the area of multiphase flow and continuing to promote a strong working relationship with the oil and gas sector are key priorities of the new Director.

Editorials

Clifford L. Redus

As of July 1, 1999, I have taken the clip board from Dr. Jim Brill as Executive Director of TUFFP. I kind of feel like coach Frank Solich, the new head football coach at Nebraska, who took Tom Osborne's place. As head football coach at Nebraska Tom Osborne racked up an incredible number of wins over the 25 years he lead the program. He established a football dynasty that will be hard for his successor to match. Like Tom Osborne, Jim Brill has provided leadership, inspiration and guidance to TUFFP for 27 years and built TUFFP into a world class mutliphase research program. Can TUFFP survive with a new guy in charge? Only time will tell but what I can promise you is we will carry on with the themes that have brought success to the program in the past. The keys to this success include listening to member companies and taking feedback to change the direction of the program as needed and focusing on problems that are of practical use to the industry and important to the member companies. We will continue to strive for excellence in our research and to transform students into engineers that will make a difference in their companies. My intent is to carry on with one of Jim's best practices, which is the desire and willingness to talk and interact with member company representatives. Lastly, even though Jim will be stepping down from his faculty position next year, he has given me his assurance that he will continue to be an active part of the leadership of TUFFP and significantly involved with our students on their research projects.

James P. Brill

Life is good! I am once again able to have exciting technical discussions with graduate students, communicate more frequently with member companies about important multiphase problems, promote technology transfer and not worry about administrative stuff. We have successfully recruited an outstanding replacement for me in Dr. Cliff Redus. Cliff arrived in Tulsa in June, is now fully settled, and officially took over as Director of TUFFP on July 1. We have already established an excellent working relationship and I take great comfort in knowing that TUFFP is in such capable hands.

My plans for early retirement are proceeding on schedule. I gave myself the title Director Emeritus of TUFFP and nobody has objected so far. By the time you receive this newsletter, I will have begun a half-time sabbatical leave for the academic year (September-May). This fall, I will continue to devote half time to TUFFP and our Paraffin Deposition research. I will participate in the September Advisory Board meetings, promote the new Wax Consortium, and call on as many TUFFP members and potential Wax members as time permits. These contacts are vitally important to ensure our research plans coincide with your problems. In the spring, I plan to teach a graduate course on Multiphase Flow in Pipes at the Colorado School of Mines. Marilyn and I will physically relocate in the Golden, Colorado, area for about four months, returning to Tulsa several times for meetings with member companies and students. Since we will move into a new home in Tulsa in November, the desire to return periodically will be even greater.

Now for some personal projections. The next few years will be difficult ones for all research consortia as we face more mergers and companies continue to pursue rigorous cost reductions. We have suffered a significant decline in TUFFP membership for 1999 and for 2000 and have taken drastic steps to control costs for the remainder of 1999 and during 2000. We plan to vigorously pursue expansion of our membership and modification of past membership criteria to encourage participation by software companies. We also intend to expand our current membership base to include service companies, contractors and consultants. In June, Cliff and I visited Norsk Hydro and Statoil in Norway. We will be calling on many more potential members and some current ones in the coming months. Maintaining oil prices at or above the $20 range is critical.

I am convinced that the research projects we have planned will be very important to TUFFP members in coming years as the industry continues its move into deepwater. Companies will like the changes being introduced by Cliff . . . they will ensure that all future projects are even more focused to properly address the multiphase flow problems encountered by members.

It is my intention to stay active in TUFFP and the new Wax consortium for several more years, but on a part time basis. Once again, I cherish the many years that this industry has supported my research program and urge you to maintain or initiate your membership in both TUFFP and the new Wax consortium for 2000.

BP Amoco Donates Flow Loop to TUFFP

BPAmoco has donated to TUFFP a multiphase flow loop previously located at their Sunbury Research Center, west of London. Recently completed discussions on the donation of the flow loop had been underway since December 1997. The flow loop is six inches in diameter, approximately 200 feet long, and uses air and water for the flowing fluids at low pressure. BPAmoco has disassembled the flow loop in England and shipped the flow loop to The University of Tulsa North Campus. A significant amount of site preparation has been completed in preparation for reassembling the loop. Our goal is to have the flow loop operational sometime during the fourth quarter of 1999. In exchange for the gift, BPAmoco has been granted permission to utilize the test facility for training purposes in the future. Access to this flow loop will significantly enhance TUFFP research in the hilly terrain pipeline area and provide TU with a world class training environment for multiphase flow in pipes.

TUFFP 1999 Short Course, A Great Success!

The TUFFP short course "Two-Phase Flow in Pipes" was again successfully taught in Tulsa, Oklahoma at the Marriott Southern Hills Hotel on May 10 – 14, 1999. The course was taught by Dr. Jim Brill and Dr. Cem Sarica who is now an Associate Professor of Petroleum Engineering at Pennsylvania State University. Twenty students attended the course, 16 from member companies and 4 from non-member companies. The course was structured to give participants a well-grounded understanding of the fundamentals of two-phase flow through pipes and restrictions. The next scheduled date for the short course is May 8-12, 2000. Additional information on the next short course can also be obtained from the Continuing Education website at www.conted.utulsa.edu.

2000 TUFFP Short Course

Assuming that we have continued support from member companies, our plan is to again teach the TUFFP short course titled "Two-Phase Flow in Pipes". Over the last several years we held the short course in Tulsa, Oklahoma. This is our preferred location to teach the course but we will tally the member company feedback on preferred locations before we make a decision on the location. The course will be taught by Dr. Jim Brill and Dr. Cliff Redus. The next scheduled date for the short course is May 8 - 12, 2000. Additional information can be obtained from the Continuing Education website at www.conted.utulsa.edu. With the turnover that is occurring in work groups in your companies, we would encourage you to place new engineers that are new to the area of multiphase flow in the course to jump start their productivity in this area.

1999 Questionnaire

The 1999 Questionnaire was distributed to official Advisory Board Representatives by email. This year, in addition to asking you to rank potential research projects, we have included a general section of questions concerning administration of TUFFP. Questions cover areas such as where we should hold our short courses, your satisfaction with the level of correspondence we send out, the computer language we should be using, the content of our new web site and a general solicitation of surplus equipment. We also want any other suggestions that you have to improve our program. As the new executive director of TUFFP, I have the obligation and responsibility to ask member companies how we are doing and solicit feed back on how we can improve the program. In my opinion, this is one of our most important tasks because the results help us to focus our research program on significant problems as opposed to academic problems. We realize that you are busy but if you will take the time to fill in the questionnaire, we will review and consolidate member input and use the feedback to guide us in selecting new projects and with the general administration of the TUFFP program. Your candid responses are welcomed.

Consolidation Impacts TUFFP Membership

Three companies have indicated that they will be dropping their 1999 membership, ARCO Oil and Gas, Petronas, and Shell Internationale Petroleum MIJ B.V.(SIPM). This leaves our 1999 membership at 24 companies. Three other companies have informed us that they will terminate their 2000 membership, Arabian Oil Company, Ltd., Petrobras, and Pertamina. Because of mergers, we anticipate losing Amoco Production Company and Mobil Research and Development Company as well in the year 2000. Feedback from member companies that terminated indicate the cause was a tightening business climate and not dissatisfaction with the TUFFP program.

Now that the oil price is back above $20 per barrel, we are optimistic that we will be successful in bringing in new member companies to TUFFP. Current discussions are underway with the U.S. Department of Energy, Statoil, Norsk Hydro and Schlumberger. We will also be soliciting membership in E&P construction companies and software development companies.

TUFFP Web Page Progress

Our web page is located at www.tuffp.utulsa.edu. If you have not visited the site, take a few minutes and tour the site. Our web master, Trina Lao, has been busy taking feedback she got from the last Advisory Board Meeting and updating and improving the site. Improvements include a "what's new section", a status of current research projects, a calendar of upcoming events, pdf files of recent newsletters and the 1999 membership status. In the member only sections, we have included completed research reports again in pdf format. The first is by Avni Serdar Kaya – titled Compressive Mechanistic Modeling of Two-Phase Flow in Deviated Wells.

We are working on adding a new feature that will enable users to specify the operating conditions in a pipe as well as the inclination angle and then enable them to generate a flow regime map based on the Taitel-Dukler method.

Please continue to send us your suggestions on how to make your visit to our web page profitable.

SPE Monograph for Sale in September

Dr. Brill and Dr. Hemanta Mukherjee have indeed completed all writing and editing for the SPE Monograph on "Multiphase Flow in Wells." SPE moved the monograph into the two-month production stage in mid July and anticipates the monograph being available for sale at the SPE Annual Technology Conference and Exhibition in Houston, October 3-6. There is a good possibility that copies of the monograph will also be available for a signing party at the TUFFP Advisory Board Meeting Reception in Tulsa on September 30.

New Paraffin Deposition Research Consortium Plans Underway

In June, 1999 the four-year Paraffin Deposition JIP at The University of Tulsa officially ended. A bridging grant by the DOE provided funding to extend the JIP until December 1999. Final activities dealing with data analysis, modeling and report preparation will continue into the fall. With the conclusion of the Paraffin Deposition JIP, The University of Tulsa now has two extremely versatile experimental test facilities that must be used for additional research on paraffin deposition. Plans are underway to form a new focused research consortium to continue our efforts in the area of paraffin deposition. A proposal has been mailed world wide to form a focused consortium with an annual budget between $700,000 and $800,000. We hope to seek funding at the 50 percent level from the U.S. Department of Energy with the remainder being funded from membership fees from participating companies. An annual membership fee of $30,000 per year will require membership from 12 to 13 companies. A projected starting date of January 1, 2000 has been established.

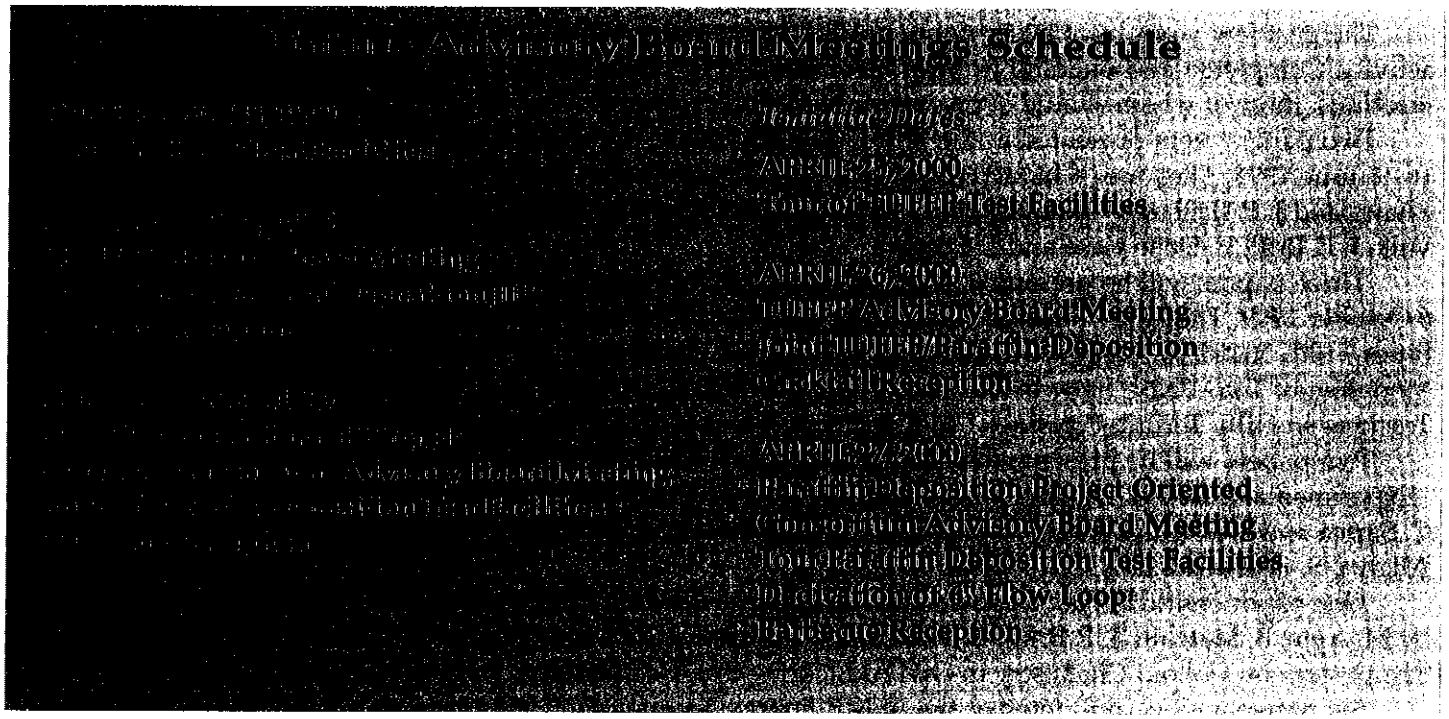
Don't Forget!

Fluid Flow Projects Advisory Board Meeting - September 29, 1999
Paraffin Deposition JIP Advisory Board Meeting - September 30, 1999

Fall 1999 TUFFP Advisory Board Meeting

Final plans have now been made for the Fall 1999 TUFFP Advisory Board and related meetings. All meetings will be held at the Sheraton Tulsa Hotel. Note that this is the first time our meetings have been held at this hotel. The TUFFP Advisory Board meeting will begin at 8:30 a.m. on Wednesday, September 29, 1999 and will adjourn at 5:00 p.m. A tour of test facilities for persons attending the TUFFP Advisory Board meeting but not staying for the Paraffin Deposition JIP Advisory Board meeting will be held at 3:00 p.m. on Tuesday, September 28, 1999. Following the Advisory Board meeting on Wednesday there will be a reception at the Sheraton Tulsa Hotel from 6:00 -8:00 p.m. and TUFFP members will be joined by those attending the Paraffin Deposition JIP Advisory Board meeting that will be held the following day, September 30, 1999. Immediately after the Paraffin Deposition JIP Advisory Board meeting there will be another tour of test facilities at 5:00 p.m., followed by a barbecue dinner on the North Campus at 6:00 p.m.

The Request for Information form and the Hotel Information form are included with this newsletter. All persons from your company that plan to attend the Advisory Board meetings should complete and return these forms as soon as possible to enable us to plan accordingly.



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

ETCE 2000 Looking Good

The technical program for the combined ASME Energy Technology Conference and Exhibition (ETCE) and the Offshore Mechanics and Arctic Engineering (OMAE) looks fantastic for New Orleans, 14-17 February 2000. The combined ETCE 2000 & OMAE 2000 conference feature title is "Energy for the New Millennium." A Symposia at the conference that will be of special interest to TUFFP members will be the Petroleum Production Technology Symposium. Building on the successes of ETCE '98 (21 papers) and ETCE '99 (28 papers), the Production Technology Symposium for ETCE 2000 will feature over 90 papers in 31 technical sessions. All papers will be included on a CD ROM made available to all registrants.

ETCE 2000 Production Technology Sessions will include: 4 sessions on Multiphase Flow in Pipes, 4 sessions on Environmental Issues, 3 sessions on Erosion and Corrosion, 3 sessions on Separation, 3 sessions on Horizontal Wells, 2 sessions on Flow Assurance, 2 sessions on Formation Damage, 2 sessions on Oil-Water Flow, 2 sessions on Artificial Lift, 2 sessions on Optimization, 1 session on Metering, 1 session on Multiphase Pumping, 1 session on Inflow Performance Relationships, and 1 session on Simulation Methods.

The large number of papers accepted will require three concurrent sessions for all time slots on Monday, Tuesday and Wednesday. In addition, the traditional Gas Lift Workshop will be held on Wednesday and Thursday.

TUFFP/Wax Personnel Present Several Publications

The past few years have been highly productive ones for TUFFP and Paraffin Deposition research activity. Completed and ongoing projects have resulted in preparation of 14 technical articles for various meetings, most of which should soon appear in various journals.

Two papers were presented at the BHRG International Conference on Multiphase Flow, Cannes, France, 16-18 June 1999. They are "Characterization of Slug Dissipation in Downward Flow," H. Yuan, C. Sarica, H. Zhang and J. P. Brill and "Investigation of Multiphase Flow Paraffin Deposition," M. Apte, B. Matzain, M. Volk, J. P. Brill, E. Delle Case and J. Creek.

Three papers will be presented at the SPE Annual Technical Conference and Exhibition, Houston, TX, 3-6 October 1999. They are "Experimental Study of Low Liquid Loading Gas-Liquid Flow in Near-Horizontal Pipes," SPE 56466, W. Meng, X. T. Chen, G. E. Kouba, C. Sarica and J. P. Brill, "Comprehensive Mechanistic Modeling of Two-Phase Flow in Deviated Wells," SPE 56522 A. S. Kaya, C. Sarica and J. P. Brill and "Slug Tracking in Hilly Terrain Pipelines," SPE 56521, Y. Taitel and D. Barnea (research sponsored by TUFFP).

Two papers will be presented at the AIChE Annual Meeting, Dallas, TX, 1-5 November 1999. They are "Experimental Study of Droplet Entrainment in Near-Horizontal Pipes," W. Meng, J. P. Brill, X. T. Chen and C. Sarica and "A Comparison of Models to Predict Pressure Gradient for Horizontal Oil-Water Flow," B. Alkaya, S. Jayawardena and J. P. Brill.

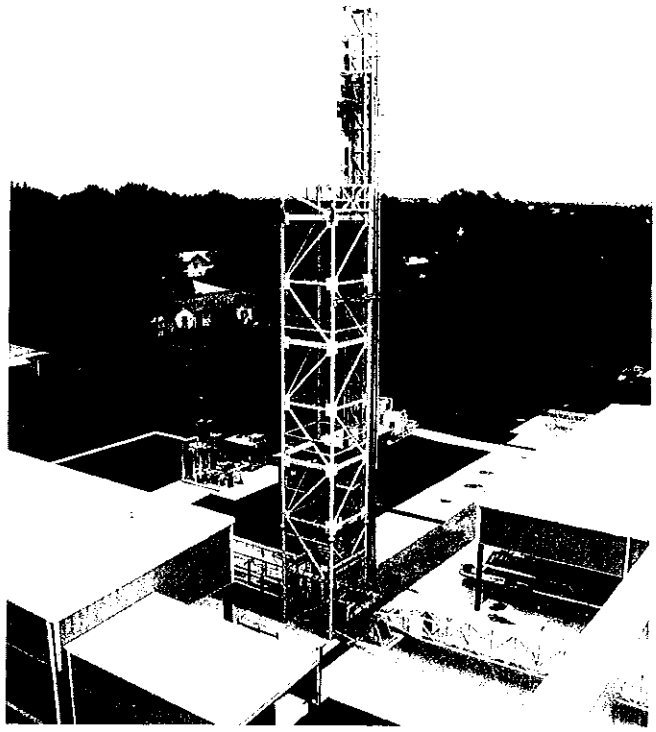
One paper entitled "Wax Deposition in Multiphase Flowing Gas-Oil Systems - New Experimental Data" by M. Apte, B. Matzain, J. P. Brill, M. Volk, and J. L. Creek will be presented at the Third International Symposium on Colloid Chemistry in Oil Production (ISCOP), Huatulco, Oaxaca, Mexico, 14-17 November 1999

Six papers will be presented at the ASME Energy Technology Conference and Exhibition, New Orleans, LA, 14-16 February 2000. They are "Two-Phase Flow in a Hilly Terrain Pipeline," E. Al-Safran, J. P. Brill, S. Jayawardena and H. Zhang, "An Experimental Study of Slug Dissipation in Downward Flow," H. Zhang, H. Yuan and J. P. Brill, "Slug Dynamics in Gas-Liquid Pipe Flow," H. Zhang, S. Jayawardena, C. Redus and J. P. Brill, "Investigation of Paraffin Deposition During Multiphase Flow in Pipelines and Wellbores – Part 1 – Experimental Investigation," B. Matzain, M. Apte, H. Zhang, M. Volk, J. P. Brill and J. Creek, "Investigation of Paraffin Deposition During Multiphase Flow in Pipelines and Wellbores – Part 2 –Modeling," M. Apte, B. Matzain, H. Zhang, M. Volk and J. P. Brill and "Oil-Water Flow Patterns in Slightly Inclined Pipes," B. Alkaya, S. Jayawardena and J. P. Brill.

In addition, a article entitled "Oil-Water Flow Patterns in Horizontal Pipes," by J. L. Trallero, Y. Taitel, C. Sarica, S. Jayawardena has recently been submitted to the International Journal of Multiphase Flow.

Paraffin Deposition JIP Update

A large Joint Industry Project (JIP) was initiated at The University of Tulsa on May 1, 1995, to investigate paraffin deposition under both single-phase liquid and multiphase flow conditions in pipelines and wellbores. This $4.2 million, four-year project is funded by membership fees and donations from 37 domestic and international oil and gas related companies, DOE, and the US Department of Interior's Minerals Management Service. The JIP is coordinated through five committees chaired by industry members. Deliverables in the form of literature searches, computer programs, experimental data, and reports describing models for predicting deposition phenomena are scheduled throughout the four-year study. Monitoring of progress in the JIP is accomplished through committee meetings and semi-annual Advisory Board meetings.



Two-Phase Test Section - Vertical

The University of Tulsa has received $165,000 of supplemental funding from the United States Department of Energy (DOE). These funds will support the wax JIP through December 1999 at which time it is anticipated that a new project oriented wax consortium will begin. These funds will allow The University to satisfactorily complete the proposed JIP research.

The test matrix for investigating paraffin deposition during multiphase flow was refined. Conclusions drawn from the outcome of the flow pattern tests and preliminary wax deposition tests were used to refine the test matrix. Several additional multiphase tests were added. All planned multiphase tests have been completed. This quarter, thirteen multiphase deposition tests have been completed: one repeat test with the boom in the horizontal position, eight tests with the boom in the vertical position, and three tests with the boom in an inclined position. However, several repeat tests and possible additional tests will be required upon completion of the analysis of the data. The acquired data will be analyzed next quarter and refinements will be made to the multiphase flow paraffin deposition model and computer program.

Multiphase Solutions, Inc. (MSI) is nearing completion of incorporating the multiphase wax deposition computer code into a Graphical User Interface (GUI). A preliminary version of the GUI will be delivered to the University for testing of both the GUI and the Fortran code next quarter. The user's manual will be modified to include the new multiphase flow code.

The next Advisory Board Meeting will be held on September 30, 1999. The purpose of this meeting will be to present the findings from the multiphase studies and to review the status of forming the new Project Oriented Wax Consortium. A reception will be held on September 29th from 6:00 to 8:00 p.m. A tour of the facilities will be held on September 30th following the Advisory Board Meeting. A workshop on the final prediction model and computer program for JIP members to be held in Houston is planned for early December after MSI delivers the GUI for the multiphase flow deposition program.

Low Liquid Loading Two-Phase Flow in Near-Horizontal Pipelines

Gas-liquid two-phase flow with a small amount of liquid is frequently encountered in natural gas pipelines. Even when single-phase gas enters a pipeline, condensate traces can be formed by retrograde condensation. The presence of the liquid can lead to a significant increase in pressure loss over that for single-phase gas flow. Despite numerous theoretical and experimental investigations into gas-liquid pipeline flow, only a few studies have focused on low liquid loading two-phase flow in the recent literature and the topic has not been adequately studied. Existing models do not predict the flow characteristics of gas-condensate mixtures in natural gas pipelines with sufficient accuracy.

Dr. Weihong Meng putting the finishing touches on his dissertation

The objective of this project is to investigate, experimentally and theoretically, low liquid loading two-phase flow in near-horizontal pipelines. Both stratified-wavy and annular flows, the most common flow patterns encountered in gas pipelines, are being studied.

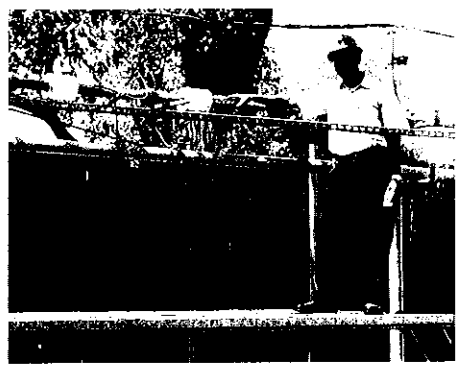
The designed tests have been completed for the study and analysis of the data is complete. The data analysis revealed the inadequacy of the Taitel-Dukler flow pattern transition model for upward inclined flow under the low liquid loading conditions. Modeling of the interface was identified as the major source of the discrepancy. Weihong Meng is scheduled to complete the final report in September 1999.

Two Phase Flow in Hilly Terrain Pipelines

Hilly terrain pipelines are inevitable in field operations. Both offshore seafloor and onshore land exhibit hilly terrain configurations. The prediction of flow behavior for hilly terrain pipelines is important to properly manage hydrocarbon recovery. Hydrodynamics slugs generated in uphill sections may or may not decay in following downhill sections, causing uncertainties in pressure behavior. Such configurations can also result in terrain induced slugs that are much longer than those normally encountered in horizontal pipelines. These long slugs often cause operational problems, flooding of downstream facilities, severe pipe corrosion, and structural instability of the pipeline, as well as production loss and poor reservoir management due to unpredictable wellhead pressures.

Eissa Al-Safran "cramming" for Ph.D. Qualifying Exam

In this study, two phase flow in a hilly terrain pipeline will be investigated experimentally and theoretically. The objectives of this project are to design, construct and validate an experimental facility to study slug flow in a single hilly terrain pipeline unit, acquire a limited data set of two-phase flow in a hilly terrain pipeline, describe the physics of slug initiation in the bottom elbow, and to provide closure relationships to be used in slug tracking models.



Eissa Al-Safran observing slug flow

An existing TUFFP test facility was modified to conduct the experimental part of this study.

The instrument calibration has been completed, and the test loop was successfully used for data acquisition. Twenty tests were conducted with different combinations of superficial gas and liquid velocities. Analysis of the collected data is in progress, and the following will be studied: slug initiation at the bottom elbow, slug frequency, slug length and slug translational velocity along the hilly terrain test section.

Oil - Water Flow Patterns in Slightly Inclined Pipelines

Banu Alkaya conducting oil-water flow tests

A systematic research program has been underway at TUFFP since 1992 to investigate oil-water flow in wellbores as well as pipelines. Trallero et al. classified the flow patterns for horizontal oil-water flow, based on both his experimental data taken at the TUFFP Oil-Water Flow Facility, and data from several other sources. A new mechanistic model was developed based on a rigorous two-fluid model and a force balance between gravity and turbulent fluctuations normal to the main flow. Comparisons of the model with data from his research and from several other studies showed that the Trallero flow pattern model performs very well for horizontal pipelines. In a recent study by Flores, the flow patterns for oil-water flow were investigated for the inclination angle range from 45° to 90° and models for vertical upward flow were developed.

Although there are no perfectly horizontal pipelines, research on the flow of oil-water mixtures in slightly inclined pipelines is almost nonexistent. The objective of this project being conducted by Banu Alkaya, is to develop mechanistic models to predict the transitions of oil-water flow patterns for slightly inclined pipelines. Experimental data will be obtained at various flow conditions and inclination angles using mineral oil and water.

Banu Alkaya

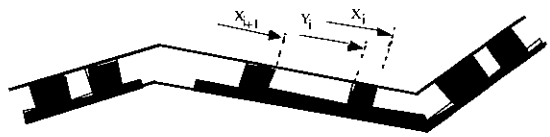
A comprehensive review of the literature has been completed. A new test section has been designed and built with completely new instrumentation. A new three-phase separator was donated to the project by Natco. The calibrations for the test instruments have been completed and a test matrix has been defined. Horizontal oil-water tests have recently begun and test results will be presented at the Fall 1999 Advisory Board Meeting.

Slug Tracking in Hilly Terrain Pipelines

Theoretical:

In the April Quarterly report a detailed description of the mathematical and numerical basis for the slug-tracking model was reported. An SPE paper based on the report has been written and will be presented at the Annual Technical Conference and Exhibition in Houston to be held October 3 – 6, 1999.

As previously reported, the objective of this program is to develop a slug-tracking program that will be able to simulate slug behavior in hilly terrain pipelines. Every slug in the pipe is traced by the variation of the position of its front X_i and its back Y_i with time.



The simulator status in the last report included the compressibility effect of the gas using ideal gas behavior. During the last six months the following additions/changes were implemented:

1. Black oil properties were implemented. The "TUFFP CORE SOFTWARE USERS MANUAL" was used to calculate the properties of the oil.

2. The continuity relations that were used in this program were modified to include mass transfer.

Evolution of gas bubbles from solution in the oil and the corresponding increase in the in-situ gas oil ratio with decreasing pressure are calculated (In the previous version mixture quality was assumed constant).

3. Inlet conditions were modified. In the last version the inlet conditions were given as the superficial mixture velocity, liquid slug length and slug unit length. The inlet conditions were modified to be based on total mass input flow rate and initial liquid slug lengths only. Inlet pressure is calculated based on the separator pressure and all other inlet variables such as quality, X, and slug unit length are calculated using black oil properties.

4. Debugging of the program is constantly in progress. The program is still not free of bugs. Owing to the large number of possibilities, many checks must be performed in order to make sure that the Code is valid for all operational conditions.

Experimental:

We have just completed a study of slug flow in the developing region in vertical flow. This experimental program was initiated before the commencement of the present project but was completed just recently and the results are relevant to TUFFP members and the slug-tracking program.

This research concerns the study of the interaction between two consecutive Taylor bubbles rising inside a vertical pipe filled with liquid. It is generally assumed that, for fully developed slug flow, the separation distance between two successive Taylor bubbles is large enough, and the bubbles propagate with an identical velocity. However, in the developing region of slug flow, some of the Taylor bubbles may be separated by short liquid slugs. In this case, the nose of the trailing bubble is influenced by the velocity field in the wake of the one ahead. The trailing bubble moves faster than the leading one and eventually coalesces with it.

The objective of the present study was to determine the distance between two injected Taylor bubbles above which the probability of coalescence becomes negligible and to measure the velocity of a bubble as it approaches a leading bubble.

The main technique used for measuring the bubble velocity and shape is via a sequence of video photographs using halogen light. The picture below is an example taken out of a sequence of pictures that shows how a bubble approaches the tail of a leading bubble and how the shape of the nose, normally fairly circular, changes when it comes closer to it.

The present study was carried out by Carlos Aladjem, an M.Sc. student, with the help of Rene van Hout, a Ph.D. student.

1999 Fluid Flow Projects Membership

Amoco Production Company
Arabian Oil Co., Ltd.
Baker Atlas
BP Exploration
BG plc
Chevron Petroleum Technology Company
Conoco, Inc.
ECOPETROL/Instituto Colombiano del Petroleo
Elf Aquitaine
Exxon Production Research Company
Institut Francais du Petrole
INTEVEP
Japan National Oil Corporation
Marathon Oil Company
Minerals Management Service
Mobil Research and Development Corporation
Pemex
Pertamina
Petrobras
Phillips Petroleum Company
Saudi Arabian Oil Company
Simulation Sciences, Inc.
Texaco
TOTAL
UNOCAL

Two-Phase Flow Calendar

33rd National Heat Transfer Conference, Albuquerque, New Mexico (session on Experimental Study of Multiphase Flow)

TUFFP Advisory Board meeting, Tulsa, Oklahoma

Paraffin Deposition JIP Advisory Board meeting, Tulsa, Oklahoma

SPE Annual Technical Conference and Exhibition, Houston, Texas

AIChE Annual Meeting, Dallas, Texas

Third International Symposium on Colloid Chemistry in Oil Production (ISCOP), Huatulco, Oaxaca, Mexico

ETCE 2000 & OMAE 2000 Conference "Energy for the New Millennium", New Orleans, Louisiana

TUFFP Advisory Board meeting, Tulsa, Oklahoma

Possible Paraffin Deposition Consortium meeting, Tulsa, Oklahoma

BHRG 2nd North American Conference on Multiphase Technology, Banff, Alberta, Canada

SPE Annual Technical Conference and Exhibition, Dallas, Texas

4th International Conference on Multiphase Flows, New Orleans, Louisiana

BHRG Conference on Multiphase Production, Cannes, France

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