THE UNIVERSITY of TULSA

TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

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TU's New Administrative Assistant

Pam Clark

I would like to take this opportunity to introduce myself as the new administrative assistant for Fluid Flow Projects. I have been working at The University of Tulsa since September 1995, previously as the Petroleum Engineering Department secretary. I especially like being involved on a daily basis with the multicultural environment of the department — students and member company representatives from around the world. I am looking forward to a long and rewarding career with TUFFP.

I am a native Tulsan. I have been married for 24 years and have two children that attend The University of Tulsa. My son, William, will graduate this May and will attend the University of Oklahoma College of Medicine. My daughter, Andrea, is majoring in nursing and plans to graduate in 2000. I am a graduate of Northeastern State University in Tahlequah with a major in criminal justice/paralegal. In my spare time, I enjoy volunteer work, volleyball, gardening, and travel.

Volk Expands TUFFP Affiliation

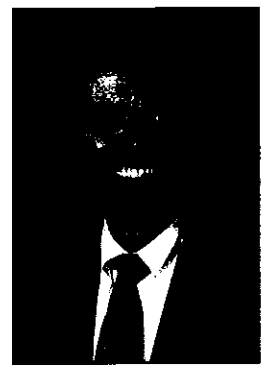
Mike Volk

Mike Volk joined The University of Tulsa in April, 1994, as manager of research and technology development. He is currently a co-principal investigator with Jim Brill in the Paraffin Deposition JIP. He also works with directors of TUFFP and other research consortia to promote JIPs beyond the scope of existing programs. He is also the director of the Russian American Oil & Gas Technology Center, whose objective is to foster business relationships between Russia and the U.S.

Mike assists the University in its role as a partner with BDM-Oklahoma for the management and operation of the U.S. Department of Energy's National Oil Program including the National Institute for Petroleum and Energy Research in Bartlesville, Oklahoma. The University and BDM-Oklahoma were awarded a contract in 1993 in which the University conducts research and technology transfer in petroleum exploration and production, petroleum processing, and related environmental areas.

Mike's background includes oil and gas experience with major oil companies, consulting/service companies, and university/government research agencies. He holds B.S. and M.S. degrees in mechanical engineering and a Ph.D. in chemical engineering, all from Penn State University.

Brill Elected to National Academy of Engineering



Jim Brill

James P. Brill, petroleum engineering professor and Executive Director of TUFFP, has been elected to the National Academy of Engineering, a national organization of distinguished engineers.

Brill, who holds TU's Floyd M. Stevenson Endowed Professorship in Petroleum Engineering, is among 85 engineers named to membership in the academy and eight named as foreign associates.

The academy said membership honors those who have made "important contributions to engineering theory and practice" and those who have demonstrated "unusual accomplishment in the pioneering of new and developing fields of technology." Election to the academy is considered to be among the highest professional distinctions afforded an engineer.

The academy is part of the National Academy of Sciences, which brings together experts in science and technology who serve as volunteers to address critical national issues and give advice to the federal government and the public.

The induction ceremony, scheduled Oct. 7 during the academy's annual meeting in Washington, D.C., will bring the academy's total U.S. membership to 1,893 and the number of foreign associates to 153.

Other TU faculty previously elected to the academy are Enders Robinson, former geosciences professor, and Kermit Brown, petroleum engineering professor emeritus.

In its announcement, the National Academy of Engineering recognized Brill for "research in multiphase flow in pipes and its application to design and operation of oil and gas production facilities in hostile environments."

Delays in Arrival of New TUFFP Research Personnel

Visa problems have delayed the arrival of Asfandiar Ansari as a Ph.D. level research assistant in TUFFP. The earliest that he could now arrive would be at the beginning of the 1997 summer term.

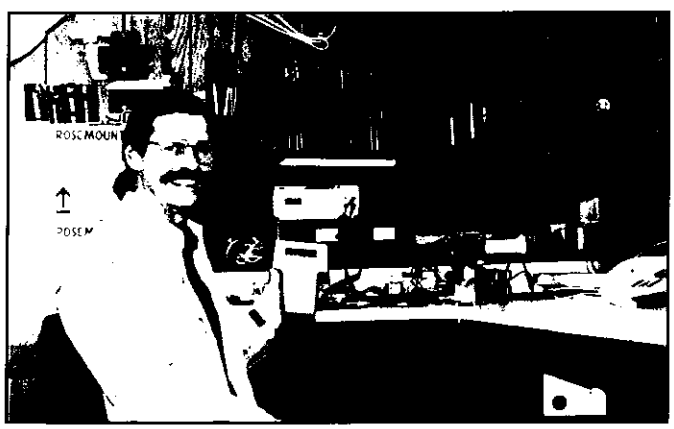
A likely research project for Ansari's Ph.D. program is expansion of our oil/water flow research to three-phase gas/oil/water flow in horizontal and deviated pipes.

Ansari completed his M.S. degree in petroleum engineering at The University of Tulsa in 1988 with his research being conducted in TUFFP. His M.S. thesis was a classic piece of work, and the mechanistic model he developed for predicting multiphase flow behavior in wells has become a standard used by many oil companies and has been incorporated into most commercial computer programs.

Eissa Al-Safran from Kuwait has found it necessary to delay the beginning of his M.S. degree program once again. At this time, it appears that he would arrive for the 1997 fall semester. Al-Safran was an outstanding B.S. graduate from The University of Tulsa in 1994. His graduate program for both M.S. and Ph.D. degrees will be fully funded by the University of Kuwait. TUFFP will fund the research portion of his graduate program.

A. S. Kaya became a research assistant in TUFFP in January 1997. He received a B.S. degree in petroleum engineering in 1994 from Middle Eastern Technical University in Turkey and is fully sponsored by the Turkish Petroleum Company. TUFFP will sponsor his research. In addition, Kaya has been working within TUFFP to prepare the data and software distribution in 1997 that is described in another section of this newsletter.

Tony Butler Promoted



Tony Butler

It is a pleasure to announce to TUFFP members that Tony Butler has been promoted to the position of senior electronics research technician within TUFFP. Tony has played a vital role for the past several years in enhancing our activities in the areas of instrumentation and data acquisition. He has worked carefully with all TUFFP and related JIP graduate students in training on modern instrumentation and the use of LabVIEW for data acquisition purposes. Congratulations, Tony!

TUFFP Adds Technician Support

Three additional temporary research technicians have been hired to assist with technician support on both TUFFP and Paraffin Deposition activities.

Steve McCutcheon was recently hired as a research technician to assist Tony Butler in our increasing instrumentation and data acquisition support for both TUFFP and Paraffin Deposition JIP activities.

Howard Rettig, a retiree from the Corps of Engineers, was hired primarily to monitor construction progress on the Paraffin Deposition JIP and to provide mechanical support for all research activities.

Billy Smith was hired to provide not only mechanical support but also any welding needs for both TUFFP and the Paraffin Deposition JIP. Billy previously worked as a TUFFP research technician in the early 1980s, so he is quite familiar with our activities and operating procedures.

Steve McCutcheon, Howard Rettig, and Billy Smith

TUFFP Announces Staff Changes

Marjel Hamlin, former administrative assistant in TUFFP, made a decision to return to college on a full-time basis effective January 1997. Although Marjel was on our staff for only a little over a year, she played a vital role in organizational changes, and her cheery personality will be missed. However, we were very fortunate to have Pam Clark fill the position. An article on Pam appears at the front of this newsletter. Her presence is especially helpful due to her familiarity with the University and the Petroleum Engineering Department, since she previously served as the departmental secretary.

Brandon Land found it necessary to resign from his position as a computer resource manager in TUFFP to devote more time to his studies. Consideration is being given to combining all expenditures from TUFFP and related JIPs to fund a full-time position to perform these duties rather than rely on students and consultants. The magnitude of expenditures would be very similar, but the continuity of effort would be greatly improved.

News

Major Telephone Upgrade Scheduled

The current telephone system on the north campus at The University of Tulsa was not capable of expansion to accommodate needs of new research programs such as the Paraffin Deposition JIP. Accordingly, the University has implemented a major upgrade of telephone equipment on the campus. The result will be a significant expansion in the number of telephone lines available. The quality of all lines will be upgraded to fiber optic status, and dramatically improved communications via the Internet will be available at all locations. The new telephone system will be operational in mid-February.

As a result of the changes, it will be necessary to incorporate new telephone numbers within TUFFP. Accordingly, a list of new telephone numbers that are effective immediately appears in this Newsletter. For a brief period of approximately six months, persons calling the previous telephone numbers will receive a recording advising them of the new telephone numbers.

TUFFP Financial Status Remains Excellent

Sincere appreciation is expressed to all TUFFP member companies for their continued financial support. One company has not yet paid their 1995 and 1996 membership fees. As of February 22nd, 1997, 9-1/2 companies have paid their 1997 membership fees. Most expenditures for 1997 are on schedule and follow the budget that was presented to member companies at the November 1996 Advisory Board meeting.

For safety and improved operating reasons, a decision has been made to replace the tower in the oil/water flow facility with a tower and boom arrangement successfully employed in other experimental research projects. Our current level of membership and reserve fund balance permits us to make these improvements without having a negative impact on our overall operation.

A detailed report on TUFFP's financial status will be reported at the April Advisory Board meeting. A preliminary analysis of probable future expenditures indicates that it should not be necessary to increase membership fees for 1998.

Data and Software Distribution Scheduled for 1997

Mr. A. S. Kaya, an M.S. student from Turkey, was hired to assist Dr. Sarica in the preparation of data and software distribution in 1997. The distribution medium will be a compact disc (CD-ROM) that is formatted in ISO 9660 standards that can be read by many platforms and computers. Data from at least four past projects will be included in the distribution, and software from six completed research projects between 1992 and 1996 will also be included.

The computer programs developed by former research assistants will be checked for their compliance with TUFFP program standards, and changes will be made if necessary.

Joint Database Project with TUFFP/Stanford Imminent

Dr. Khalid Aziz, Stanford University, and Dr. Brill have agreed to pursue an initial collaboration effort that will be mutually beneficial to both institutions. Possible components of an agreement could include: exchanging students and possibly faculty on a visiting basis; co-supervising graduate students working on selected research projects; identifying together which of our experimental data would be candidates for inclusion in a database; jointly designing database structures; and agreeing on appropriate guidelines for acknowledging contributions. A likely first candidate for some of the above activities would be the multiphase pipeline databank and modeling work conducted at TUFFP by J. J. Xiao.

The resulting joint project would create a user-friendly multiphase flow database based on Microsoft Access on a Windows platform. Stanford University has already created a framework for the database using the TUFFP Well Databank and a modified University of Calgary pipeline databank. The major benefit for TUFFP member companies would be to have our data available in a much easier to use format.

TUFFP Membership Remains Stable

Three companies — Ecopetrol (Instituto Colombiano del Petroleo), IMP (Instituto Mexicano del Petroleo), and Norsk Hydro — have terminated their membership in TUFFP. Discussions are underway with several companies that have expressed an interest in TUFFP to determine if they might become members. Below is a list of current members.

1997 Fluid Flow Projects Membership

Amoco Production Company
Arabian Oil Co., Ltd.
ARCO Oil & Gas Company
BP Exploration
British Gas Corporation
Chevron Petroleum Technology Company
Conoco, Inc.
Elf Aquitaine
Exxon Production Research Company
Institut Francais du Petrole
INTEVEP
Japan National Oil Corporation
Mobil Research and Development
Oil and Natural Gas Commission
Pertamina
Petrobras
Petronas
Saudi Arabian Oil Company
Shell Internationale Petroleum MIJ B.V. (SIPM)
Simulation Sciences, Inc.
Texaco
TOTAL
UNOCAL

Meetings

Spring 1997 Short Course Scheduled

The TUFFP short course "Two-Phase Flow in Pipes" is scheduled to be taught again in Tulsa, Oklahoma, at the Mariott Southern Hills Hotel on April 28 - May 2, 1997. Please note that this is a new location; the course has been taught at the Doubletree Hotel at Warren Place for the past several years.

Taught by Dr. Brill and Dr. Sarica, the course will give participants a well-grounded understanding of the fundamentals of two-phase flow through pipes and restrictions. Completed and current research projects permit teaching the latest techniques for designing multiphase flow piping systems for the production and transportation of oil and gas. Upon completion, the participants will be able to apply knowledge gained to design fluid flow conduits encountered in petroleum, natural gas, and chemical engineering operations.

Following is the pricing schedule for the 1997 short course.

TUFFP Member Company Seminar Fees
$950 per person (regular tuition)
$850 per person (group discount)

Non-Member Company Seminar Fees
$1,445 per person (regular tuition)
$1,195 per person (group discount)

We urge member companies to enroll engineers as soon as possible. A brochure describing the course is enclosed and includes enrollment information. If enrollment is insufficient by April 15, 1997, the course will be canceled.

Members may enroll by calling The University of Tulsa Department of Continuing Education at (918) 631-2347, sending a fax to (918) 631-2154 or e-mail to conted_cee@utulsa.edu.

Advisory Board Meetings Scheduled

Beginning with the spring 1997 TUFFP Advisory Board meeting, we will no longer hold these meetings during the same week as other research consortia in petroleum engineering. Several companies have urged us to have Advisory Board meetings for TUFFP, the Paraffin Deposition JIP, and the proposed new Slug Tracking JIP during the same week. In order to accommodate this schedule, it was necessary to select a new week for these meetings.

The next TUFFP Advisory Board meeting will be held April 22 - 23, 1997, at the Adam's Mark Hotel at Williams Center in downtown Tulsa. A Request for Information form is enclosed with this newsletter, together with information on hotel reservations and travel to and from the airport. Persons attending the Advisory Board meeting should complete the form and return it to us as soon as possible.

The Advisory Board meeting will begin at 8:30 a.m. on Wednesday, April 23, and will adjourn at 4:30 p.m. A post-meeting reception will be held in the Adam's Mark Hotel from 7:00 to 9:00 p.m. on Wednesday and will be a combined reception with the Paraffin Deposition JIP Advisory Board meeting, which will be held the following day. A tour of both TUFFP and Paraffin Deposition test facilities will be conducted on Tuesday afternoon from 3:00 to 4:30 p.m. Please note that there will not be a reception following the tour since this will now be held immediately following the Advisory Board meeting.

A summary of the dates for both April and the fall 1997 Advisory Board meetings are shown in the table below. The fall meetings are now scheduled during the week immediately preceding the SPE Annual Technical Conference and Exhibition.

TUFFP Advisory Board meeting brochures will be mailed to all members prior to the meetings. 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. A brochure containing slide copy for all presentations will be distributed at the meeting but will not be mailed to members.

BHR Group Multiphase '97 Has Excellent Program

Multiphase '97, the eighth international conference on multiphase flow sponsored by the BHR Group, will be held in Cannes, France, on June 18 - 20, 1997, at the Gray d'Albion Hotel. Approximately 60 excellent technical papers and poster session papers will be included in the program.

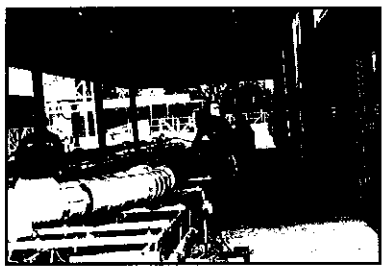
1997 Advisory Board Meeting Schedule

April 22, 1997	
Tuesday a.m.	Slug Tracking JIP Advisory Board meeting
Tuesday p.m.	Paraffin Deposition JIP Executive Committee meeting
	Tour of TUFFP and Paraffin Deposition JIP Test Facilities
April 23, 1997	
Wednesday	TUFFP Advisory Board meeting
Wednesday p.m.	Reception
April 24, 1997	
Thursday	Paraffin Deposition JIP Advisory Board meeting
October 13, 1997	
Wednesday a.m.	Slug Tracking JIP Advisory Board meeting
Wednesday p.m.	Paraffin Deposition JIP Executive Committee meeting
	Tour of TUFFP and Paraffin Deposition JIP Test Facilities
October 14, 1997	
Thursday	TUFFP Advisory Board meeting
Thursday evening	Reception
October 15, 1997	
Friday	Paraffin Deposition JIP Advisory Board meeting

Joint Industry Projects

Paraffin Deposition JIP Update

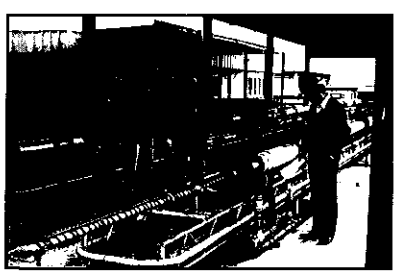
A large Joint Industry Project (JIP) was initiated at The University of Tulsa on May 1, 1995, to investigate paraffin deposition under both single-phase liquid and multiphase flow conditions in pipelines and wellbores. This $4 million, four-year project is funded by membership fees from 27 domestic and international oil and gas related companies, DOE, GRI, and the U.S. Department of Interior's Minerals Management Service. The JIP is coordinated through five committees chaired by industry members. These committees are: Flow Loop and Deposition Studies; Thermodynamics and Fluid Characterization; Heat Transfer; Operational Issues; and Technology Transfer. 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.



Single phase flow loop modifications underway

Monitoring of progress in the JIP is accomplished through frequent committee meetings and semi-annual Advisory Board meetings. The next Advisory Board meeting will be held in Tulsa on April 24, 1997, the day after the TUFFP Advisory Board meeting. The purpose of this update is to describe progress made in the JIP since the last TUFFP Advisory Board meeting on October 4, 1996.

The Flow Loop & Deposition Studies committee met November 22, 1996, in Tulsa and approved the instrumentation selection for the single-phase loop, developed preliminary guidelines and parameter matrices for future single-phase tests, and approved the conceptual design for the high pressure two-phase flow loop. Equipment suppliers for all instrumentation required for the single-phase loop were identified, and purchasing was initiated. Fisher-Rosemount agreed to provide instrumentation at a 50 percent discount. Moyno Industrial Products/R&M Tri-Phase Systems agreed to donate all progressing cavity pumps, drives, and Alan Bradley controls needed for both flow loops. Simulation Sciences agreed to make their Provision™ with PRO/II™ process simulation software available to finalize design of the two-phase flow loop. Modifications to the single-phase flow loop are underway and will continue for the next four months. Included are: cleaning of the test facility annulus region; replacement of instrumentation; installation of a new pump; adding induction heating temperature trimming sections at the oil and glycol inlets; and moving all personnel and data acquisition systems into the new Wax building.



Planning design changes in single-phase flow loop.

Test data for the four preliminary single-phase flow deposition tests conducted in September were analyzed and compiled into a report that will be distributed to JIP members in February. Exxon performed an independent analysis on the preliminary data and confirmed that predictions of paraffin deposition from temperature data agreed well with predictions from pressure drop data. Their analysis also showed that better control was needed for flow rate, improved control of inlet oil and glycol temperature was needed, and wax was partially depleted during the tests.

All fluid characterization work for the flow loop condensate was completed by Marathon Oil Co. Work continues on the Recombined Condensate (Garden Banks 426 Well A-14). Some PVT data and a high pressure cloud point are all that are needed to complete the study. The cloud point tests, bulk deposition studies, and solids analyses performed by D. B. Robinson were completed. A contract was signed with Multiphase Solutions Inc. (MSI) to complete thermodynamic modeling tasks. A general flow diagram for the overall thermodynamic computer program and Michelsen algorithms for solving flash calculations were developed. Preliminary code for the flash algorithm that will be incorporated into the Conoco program was developed and is currently under test.

Single-phase flow loop chilling system

A literature survey report dealing with heat transfer with solidification was completed by Oklahoma State University and will soon be mailed to JIP members. A comparison of the identified heat transfer correlations with five different experimental data sets obtained from the literature was also completed. Based on these comparisons, several correlations were selected and six preliminary heat transfer coefficient subroutines were developed for incorporation into the Conoco program. These heat transfer correlations performed well in predicting the heat transfer data for different flow patterns, fluid combinations, and pipe inclination angles.

Three graduate students serve as research assistants on the wax JIP. Bazlee Matzain of Petronas in Malaysia completed his M.S. degree with an analysis of the preliminary single-phase flow tests using the South Pelto oil. He is now pursuing a Ph.D. degree working on the multiphase flow deposition part of the JIP. Hans-Jacob Lund and Mandar Apte are both pursuing M.S. degrees in petroleum engineering working on the project. One will investigate detailed single phase oil tests and the other will probably investigate deposition under oil-water flow conditions. A visiting scholar, Emmanuel Del Casse of France, arrived in November to work on the project for a period of 16 months. He is fully supported by Elf Aquitaine. Dr. Tom Chen serves as the key research associate on the project, interfacing with all students on a daily basis and providing continuity for the many complex tasks that must be coordinated. A complete staff of technicians, student helpers, and a project construction engineer have been involved in preparation of the facilities. Overall supervision is provided by Dr. Brill and Dr. Mike Volk, who serve as the co-principal investigators.

Slug Tracking 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 pressure behavior in hilly terrain pipelines is important to properly manage hydrocarbon recovery. Hydrodynamic 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. This often causes 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. Therefore, there is an urgent need for an unconventional new simulator to accurately predict formation, development, and movement of slugs in hilly terrain pipelines.

Horizontal wells are increasingly being used to recover hydrocarbons. Production logging of these wells is very important to determine the flow profile along the well and consequently the performance of the reservoir and/or any enhanced recovery program. Most horizontal wells are not perfectly horizontal and can have undulations resembling hilly terrain pipelines. Horizontal wells can also operate under the bubble point pressure, causing gas-liquid two-phase flow. Flow in a horizontal wellbore is similar to that in a pipeline. The situation for undulated horizontal wells is even more complicated, considering the multiple fluid entry locations along the well and intrusive effects of a production logging tool. Interpretation of production logs becomes a challenge under such flow conditions. Therefore, what is needed is not only a quality production logging tool but also a reliable model to interpret the device responses. A reliable flow prediction model would also lend itself to better design of production logging tools for horizontal wells. A slug-tracking simulator developed for hilly terrain pipelines could also be used as a prediction model to simulate flow in undulated horizontal wells.

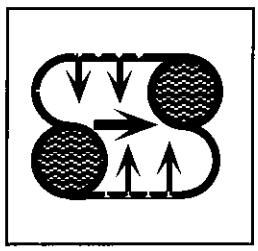
The objective of this JIP is to develop a simulator for predicting the formation, development, and movement of slugs in hilly terrain pipelines. The project will require both theoretical model development and experimental measurements. The JIP will be a non-profit, cooperative, industry-university research project undertaken by The University of Tulsa and Tel-Aviv University. This project is a major undertaking for the investigating institutions and requires their combined expertise, experience, and abilities. Slug flow data acquired will be used for both model verification and the development of closure relationships.

A stand-alone beta version of a slug tracking simulator will be delivered to JIP participants at the end of the first year. Upon completion of the project, JIP participants will receive a stand-alone complete slug-tracking computer simulator complying with TUFFP Programming Standards, necessary closure relationships, and a slug flow databank. The JIP is also pursuing several Software Companies for their early involvement with the project to ensure better utilization of the developed technology.

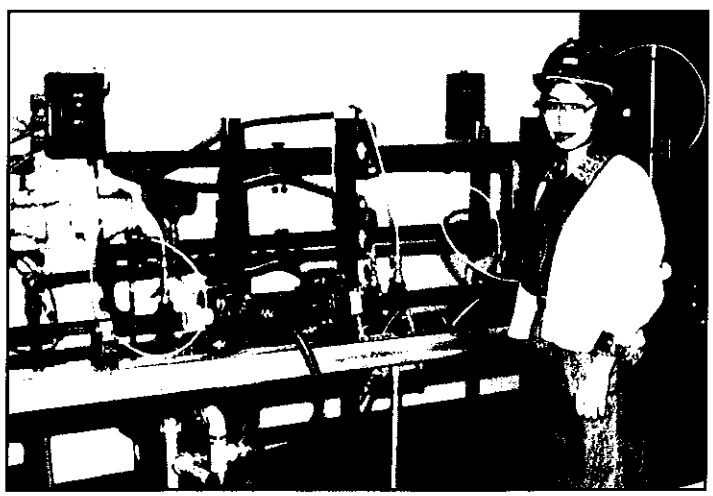
Currently, 14 major oil and gas companies have shown genuine interest in the project. We expect this number to reach 20 before the project starts. The proposal and the Letters of Agreement will be mailed to potential participants in February 1997. The project will be initiated on April 1 and will be completed in three years. The first JIP Advisory Board meeting will be held on April 22, 1997, in Tulsa, Oklahoma.

Progress Reports

Flow Behavior in Horizontal Wells



Horizontal wells can have very complex flow geometries, in part due to interaction between the main flow stream and the influxes along the wellbore, and also due to completion type. In the first phase of this project, a new generalized friction factor expression for a single perforation horizontal well was developed using the principles of conservation of mass and momentum. A simple correlation for the horizontal well friction factor was then developed by applying experimental data to the generalized friction factor expression.



Jasmine Yuan with horizontal well test facility

The objectives of the second phase of this project include investigation of the flow behavior in perforated horizontal wells and horizontal wells completed with slotted liners. The investigation of perforated horizontal well flow behavior has been completed. A new test section for single slot experiments has been designed and is under construction. Test section designs for multiple slot configurations are underway.

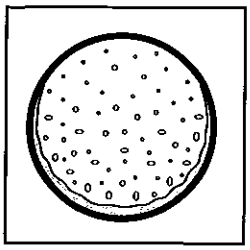
The CFD software package Fluent™ is being used to simulate the flow behavior in horizontal wells. We are in the process of evaluating different turbulent models in order to find the most suitable model for our problem.

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

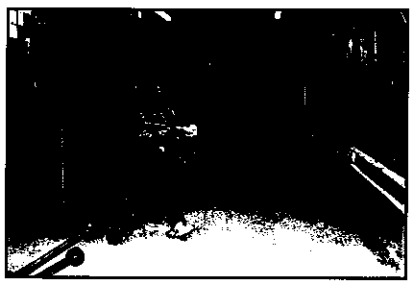
Gas-liquid two-phase flow with a small amount of liquid is frequently encountered in natural gas pipelines. Even when single-phase gas enters a pipeline, condensate traces can be formed by retrograde condensation. The presence of these traces of liquid can lead to a significantly larger pressure loss than for single-phase gas flow. Despite numerous theoretical and experimental investigations into gas-liquid flow in pipelines, only a few studies on low liquid loading two-phase flow have appeared

in recent literature and the topic has not been adequately studied. Existing simulation models do not predict the flow characteristics of gas-condensate mixtures in natural gas pipelines with sufficient accuracy.

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, will be studied. Compressed air and a highly refined oil will be used as testing fluids. Liquid film thickness distribution around the pipe wall will be measured using newly developed TUFFP capacitance probes. Total liquid holdup and liquid entrainment fraction in the gas phase will be measured using quick-closing valves and a liquid film removal technique, respectively. Pressure drops will also be measured using differential pressure transducers. Based on experimental results obtained, a comprehensive mechanistic model and its closure relationships will be developed.

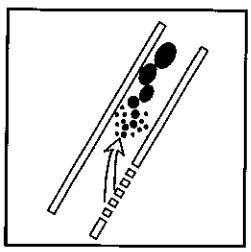


Significant progress has been accomplished since the last Advisory Board meeting on November 21, 1996. The TUFFP splitting tee test facility located on the north campus of The University of Tulsa was dismantled. The design of the new test facility was completed, is currently under construction, and will be operational by the April 23, 1997, Advisory Board meeting.



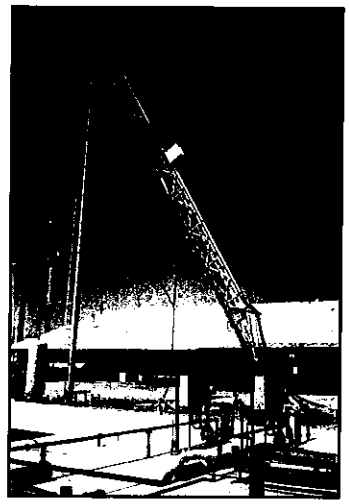
Weihong Meng assembling the low liquid holdup test facility

Oil-Water Flow Patterns in Vertical and Deviated Wells



The simultaneous flow of oil-water mixtures in wells is a common occurrence in wellbores. Its hydrodynamic behavior under most flow conditions and inclination angles constitutes a relevant unresolved issue in production engineering. In this study, tests have been conducted using a mineral oil and water (ρ_o/ρ_w=0.85, μ_o/μ_w=20.0 and $\sigma_{o\text{-}w}$=33.5 dyne/cm at 90°F) in an inclinable transparent test section (2-in. ID, 51-ft. long). Flow pattern dependent parameters, including pressure drop, holdup, and flow structure, were measured experimentally.

Analysis of experimental data from 484 flow tests allowed identification and characterization of the oil-water flow patterns existing for conditions typical of producing wells. Six flow patterns have been identified and characterized in vertical flow and seven in inclined flow, all in the domain of dispersed flow. Flow patterns common to both vertical and deviated wells include dispersions of oil in water (O/W), dispersions of water in oil (W/O) and very fine dispersions (O/W and W/O). In vertical flow, two additional flow patterns exist, designated as O/W and W/O churn flow. In deviated wells, a dispersion of oil in water can exist in three possible configurations, including countercurrent, pseudoslugs, and cocurrent flow. A transitional flow pattern occurs in inclined flow between the water dominated and the oil dominated flow patterns.



Oil/Water inclined flow test facility

Application problems associated with the identification of oil-water flow patterns in wellbores include design and interpretation of production logs, pressure drop calculations, optimum tubing selection, multiphase downhole metering, and design and modeling of artificial lift installations.

Analysis of the extensive experimental data has been completed, and adjustments to the flow pattern transition model are nearing completion. A final report will be available in March 1997.

Comprehensive Mechanistic Model for Deviated Wells

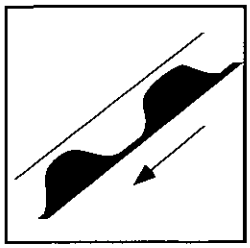
A. S. Kaya

The objectives of this project are to develop and evaluate a comprehensive mechanistic model for deviated wells. This will also involve expanding the current TUFFP well data bank and/or the multiphase flow database that will be jointly created by The University of Tulsa and Stanford University using Microsoft Access™.

Early modeling efforts concentrated on vertical wells. Ozon et al., Hasan and Kabir, Ansari et al., and Chokshi are examples of comprehensive mechanistic models developed strictly for vertical upward two-phase flow. Evaluation studies proved that mechanistic models are reliable, consistent, and perform better than empirical correlations.

Hasan and Kabir proposed the first mechanistic model for deviated wells. The Hasan and Kabir work was a step in the right direction. Since then, there have been several studies conducted on various aspects of deviated wells. Petalas and Aziz proposed a new mechanistic model that is claimed to be applicable for inclination angles from -15° to 90°. A unified flow pattern prediction method to cover the entire range of inclination angles has been developed by Barnea. Taitel and Barnea proposed a general pressure gradient prediction model for slug flow in upward inclined pipes. TUFFP has conducted a systematic research program oriented toward deviated or extended reach wells for the past six years. Slug flow behavior in deviated wells was investigated by Alves and Felizola. Annular flow behavior was studied by Paz. The next step is to develop a comprehensive mechanistic model for deviated wells utilizing the best models for flow pattern and pressure drop predictions. Currently, a literature survey is underway. The results of the survey will be presented at the next Advisory Board meeting.

Slug Dissipation in Downward Flow



Slug flow is a common occurrence in hilly terrain pipelines. The standard engineering design method has been to divide a pipeline into various sections of constant slopes and apply steady state flow models to simulate flow behavior in each section without considering the interaction between upward and downward sections. An important consequence of this interaction is carryover of large slugs into downhill sections that were created in uphill sections, even though modern flow pattern prediction models indicate that stratified flow should exist in the downhill sections. The objective of this project is to conduct an experimental and theoretical study to investigate slug flow dissipation in a hilly terrain pipeline.

Nobutoshi Shimizu preparing the facility for slug dissipation tests.

Currently, modifications of the existing inclined flow test facility are underway. The test section used in the previous study has been removed from the facility. Transparent PVC-R4000 pipes and other necessary material to build the new test section have been ordered. Thirteen capacitance sensor housings are currently being manufactured. The circuits for the sensors have already been built. It is expected that the modifications of the test facility will be completed before the April, 1997, Advisory Board meeting.

1997 Two-Phase Flow Calendar

March 9 - 11	SPE Production Operations Symposium, Oklahoma City, Oklahoma
April 2 - 4	ASME 1st Annual Energy Week Asia Conference and Exhibition, World Trade Centre, Singapore
April 22	Slug Tracking JIP Advisory Board Meeting, Tulsa, Oklahoma
April 22	Paraffin Deposition JIP Executive Committee Meeting, Tulsa, Oklahoma
April 23	TUFFP Advisory Board Meeting, Tulsa, Oklahoma
April 24	Paraffin Deposition JIP Advisory Board Meeting, Tulsa, Oklahoma
April 25	TUSTP Advisory Board Meeting, Tulsa, Oklahoma
May 5 - 8	Offshore Technology Conference, Houston, Texas
June 18 - 20	BHRGroup 8th International Conference - Multiphase 97, Cannes, France
June 22 - 26	1997 ASME Fluids Engineering Division Summer Meeting, Vancouver, British Colombia, Canada
September 14 - 19	SPE Forum on Multiphase Flow, Aviemore, Scotland
October 1	Slug Tracking JIP Advisory Board Meeting, Tulsa, Oklahoma
October 1	Paraffin Deposition JIP Executive Committee Meeting, Tulsa, Oklahoma
October 2	TUFFP Advisory Board Meeting, Tulsa, Oklahoma
October 3	Paraffin Deposition JIP Advisory Board Meeting, Tulsa, Oklahoma
October 5 - 8	SPE Annual Technical Conference & Exhibition, San Antonio, Texas
October 7 - 10	International Symposium on Multiphase Fluid, Non-Newtonian Fluid, and Physico Chemical Fluid Flows '97, Beijing, China
November 3 - 7	International Symposium on Liquid-Liquid Two-Phase Flow and Transport Phenomena, Antalya, Turkey
November 17 - 21	ASME Annual Winter Meeting, Dallas, Texas

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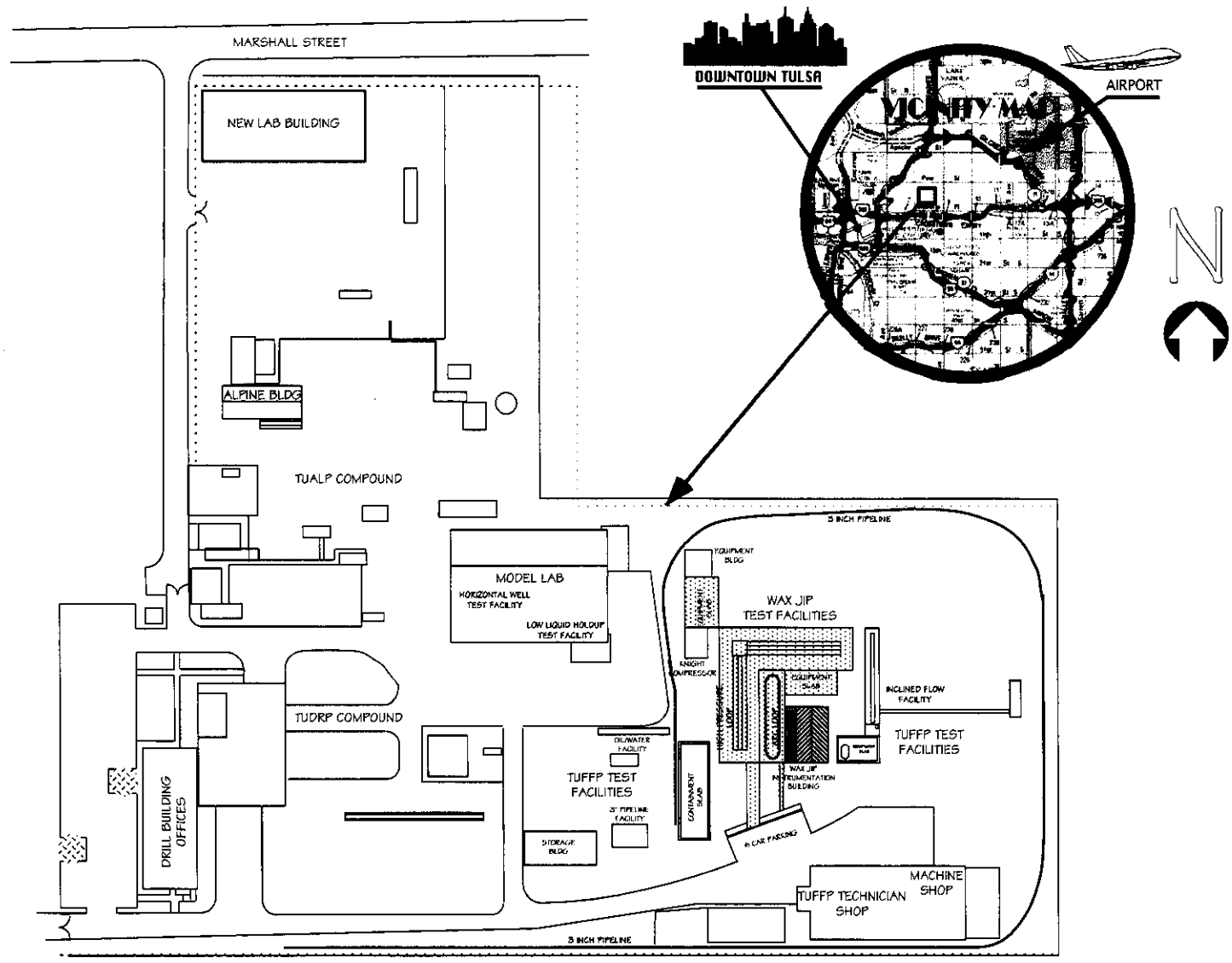

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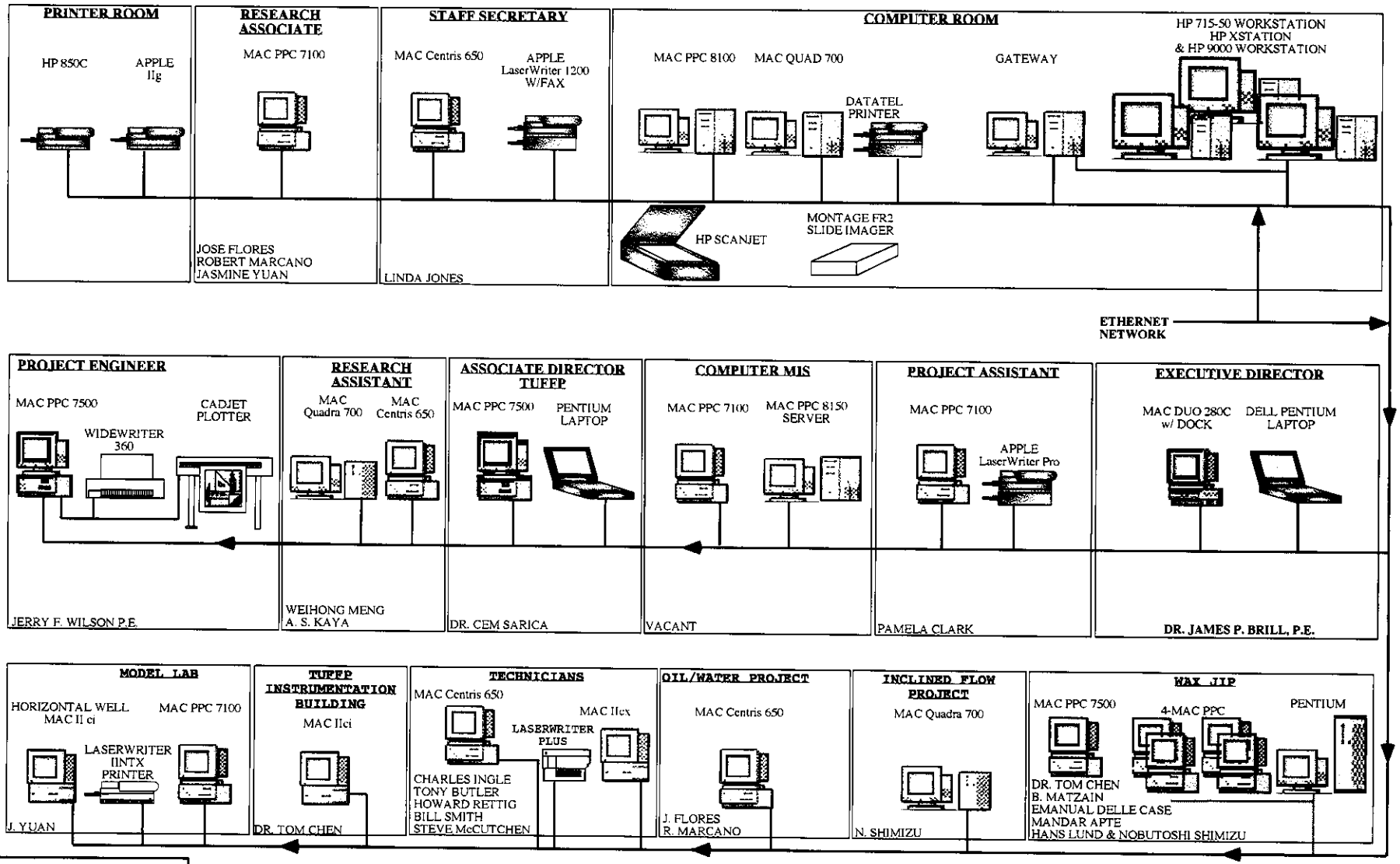
TUFFP/WAX JIP COMPOUND
SITE PLAN SPRING 1997

TUFFP/WAX JIP COMPUTER NETWORK



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TUFFP/WAX JIP COMPUTER LAYOUT DIAGRAM SPRING 1997

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