THE UNIVERSITY of TULSA

TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

SUMMER 1996 | A Semiannual Publication | Volume 10, Number 2

TUFFp Talk

Cem Sarica, Associate Director

Cem Sarica Named TUFFP Associate Director

Effective May 1, 1996 Dr. Cem Sarica was appointed Associate Director of TUFFP. For the past two years, Cem has essentially been functioning in this capacity. His activities include directing or co-directing most TUFFP research projects, and coordinating activities such as graduate seminars, preparation of progress reports, preparing students for Advisory Board presentations, and preparation of the semi-annual TUFFP newsletter.

In addition to his research activities, Cem serves as an adjunct professor in the Petroleum Engineering Department. He has taught a graduate level course on multiphase modeling, and also lectured in several other courses.

Over the past two years, Cem has served as the Principal Investigator on various contract research projects pertaining to multiphase flow in pipes but outside the realm of TUFFP. During the past year he has been involved in intense planning for the new Joint Industry Project on slug tracking. Cem will serve as the Principal Investigator in this large JIP involving The University of Tulsa, Tel Aviv University, and the Japan National Oil Corporation.

Charles Ingle Named Technical Supervisor in TUFFP

After 17 years of serving first as a Research Technician and then as a Senior Research Technician in TUFFP, Charles Ingle was promoted May 1 to Technical Supervisor. In this capacity, he becomes a salaried rather than an hourly employee. He now serves as the supervisor of all Research Technicians and student helpers for TUFFP, related contract projects and JIPs. With expanded growth of both TUFFP and Joint Industry Projects, the number of student helpers involved in construction and maintenance of test facilities, and assisting graduate students and research associates in the acquisition of experimental data has increased significantly. This appointment will permit TUFFP to improve and coordinate the activities of these support personnel.

Charles was hired as a Research Technician in TUFFP in 1979 following his retirement from the U.S. Air Force, where he served in a variety of positions dealing with aircraft maintenance. As a Research Technician with TUFFP, no one was more familiar with the complex array of test facilities, equipment, equipment vendors, maintenance requirements, and the overall support needs of the graduate students and research associates.

Howard Rettig, Charles Ingle, Technical Supervisor

New Advisory Board Meeting Schedule Established

The next TUFFP Advisory Board meeting will be held November 20 - 21, 1996 at the Doubletree Hotel at Warren Place in Tulsa, Oklahoma. A request for information form will be mailed to member companies in advance of the meeting, 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. A pre-meeting tour of TUFFP and Paraffin Deposition JIP test facilities on the North Campus of The University of Tulsa will be conducted on Wednesday, November 20 from 3:00 - 4:30 p.m. A reception following the tour will be held on the 19th floor of the Two Warren Place Building adjacent to the Doubletree Hotel at Warren Place from 6:00 - 8:00 p.m. The Advisory Board meeting will begin at 8:30 a.m. on Thursday, November 21 and will adjourn at 4:30 p.m.

Starting in the spring 1997, TUFFP meetings will no longer be held the same week as other research consortia in Petroleum Engineering. Several members have urged us to have Advisory Board meetings for TUFFP, the Paraffin Deposition JIP, and the new Slug Tracking JIP during the same week. These meetings will require approximately three days, making it impossible to include the other research consortia meetings during the same week. Accordingly, we now propose to hold the spring meetings during the middle of April each year and the fall meetings during the week immediately preceding the SPE Annual Technology Conference and Exhibition. Tentatively, the spring meetings will be held April 22 - 24, 1997 as follows:

April 22, 1997	
Tuesday a.m.	Slug Tracking JIP 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 evening	Reception
April 24, 1997	
Thursday	Paraffin Deposition JIP Advisory Board meeting

In addition to the change in schedule, it is likely that we will also have to vary our selection of local hotels. For the past several years, all activities have been held at the Doubletree Hotel at Warren Place. Scheduling conflicts with the hotel have made it necessary for us to investigate other alternatives.

BHR Group Once Again Schedules Multiphase Conference

Multiphase 97, the 8th International Conference on Multiphase Flow sponsored by BHR Group will once again be held in Cannes, France June 18 - 20, 1997. As in the past several conferences, TUFFP will once again be a co-sponsor. This conference has become one of the premier opportunities to exchange multiphase flow technology pertaining to the production and transportation of oil and gas. The call for papers for Multiphase 97 is enclosed with this newsletter.

TUFFP Short Course - Another Success!

Once again, a successful short course on two-phase flow in pipes was held May 20 - 24, 1996 in Tulsa, Oklahoma. The course was attended by 17 engineers and scientists, including 11 from 6 TUFFP member companies, 4 from 4 non-member companies, and 2 Mechanical Engineering graduate students from Oklahoma State University that are working on the heat transfer subcontract for the Paraffin Deposition JIP. Income from the course was sufficient to pay all expenses incurred. A tentative date of April 28 - May 2, 1997 has been established for the next TUFFP short course.

TUFFP Updating Data and Software Archiving

Cem Sarica has supervised Brandon Land, TUFFP Computer Resource Manager, in an effort to properly archive past experimental data and software generated in TUFFP research projects. Members will be provided this information on CD ROM and future distributions will also be accomplished on this media.

Liming Zhu, an M.S. student in Computer Science funded by the Paraffin Deposition JIP, has been devoting much of her time to learning and evaluating Microsoft Access. These efforts will better prepare us to assess the potential of using this database for improving distribution of experimental data to TUFFP and Paraffin Deposition JIP members in the future. Improved expertise in the use of Microsoft Access will also permit us to adequately evaluate the benefits of a possible cooperative database project with Stanford University that has been delayed indefinitely as we perform this evaluation.

New Research Personnel Planned for TUFFP

An offer has been extended to Asfandiar Ansari as a Ph.D. level research assistant in TUFFP. Mr. 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 which 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. We anticipate Mr. Ansari arriving in January 1997 and possible Ph.D. research projects for him include the analysis of pressure drop and holdup data from current research projects on oil-water flow in horizontal and deviated pipes or an extension of this work to three-phase flow.

It now appears that Mr. Eissa Al-Safran from Kuwait will arrive to begin his M.S. degree program in January 1997. Mr. 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 be funding the research portion of his graduate program.

Dr. Khalfan Al Asmi, a lecturer in the Department of Mechanical Engineering at Sultan Qaboos University in Oman, will join TUFFP as a Fulbright Fellow for a period of six to eight months this fall. Dr. Al Asmi holds a Ph.D. from the University of Surrey in England and has extensive experience in the design and analysis of multiphase flow equipment using CFD techniques.

Hans-Jacob Lund has been offered a research assistantship to pursue an M.S. degree in Petroleum Engineering with his research being conducted on the Paraffin Deposition JIP. Mr. Lund was an outstanding Petroleum Engineering graduate from The University of Tulsa in May 1996 and has a strong interest in both multiphase flow in pipes and paraffin deposition.

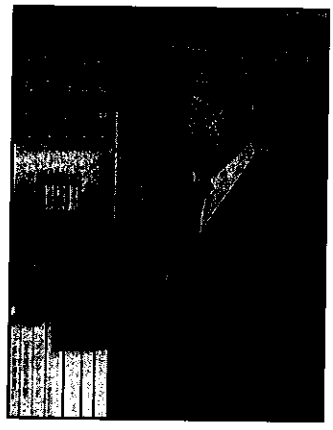
Emmanuel Delle Case will join the Paraffin Deposition JIP research team as a Visiting Scholar in November 1996. Emmanuel is a recent graduate from Toulouse University in France and will be fully sponsored by Elf Aquitaine during his stay at The University of Tulsa. His assignment with us will also satisfy his French Military Service requirement and he will probably not be pursuing a graduate degree program.

Marcano Retained as Visiting Research Engineer

In early July, Robert Marcano successfully defended his M.S. thesis research on "Slug Characteristics for Two-Phase Horizontal Flow". Final modifications of his thesis are currently in preparation with distribution to TUFFP member companies now scheduled in late September.

Robert brings to TUFFP an unusual background in which he completed approximately ten years of operations experience in the oil industry in Trinidad before pursuing an engineering degree. This background has proven to be very valuable in the operation of some of our experimental test facilities. In particular, the current research project on oil-water flow in inclined pipes being conducted by José Flores was sufficiently complex to require simultaneous efforts from several experienced researchers. Robert's appointment over the coming months will involve assisting José Flores with data acquisition, modifying the two-phase splitting test facility for use in investigating low liquid holdup flow behavior, and modifying the downflow test facility for use in investigating slug dissipation in downhill slopes.

Yehuda Taitel Returns to TUFFP



Dr. Yehuda Taitel, Professor of Mechanical Engineering at the University of Tel Aviv is again spending a period of approximately one month at TUFFP this August as a consultant on a variety of research projects. He is lending his unique expertise to assisting TUFFP researchers in their modeling problems and in the design of experimental test facilities. He is also working with Cem Sarica on final plans to establish a new Joint Industry Project on Slug Tracking.

Takagi Updates TUFFP Libraries

A recent Petroleum Engineering graduate, Lisa Takagi, was hired in June on a temporary basis to reorganize the TUFFP book and periodical libraries. Information in these libraries had become increasingly difficult to access and needed the expertise of a Petroleum Engineer to organize the complex information sources properly. This activity is nearing completion and Lisa will then become involved in one of the TUFFP research projects. Simultaneously, she is also developing a spill containment procedure that would be followed in all TUFFP and related test facilities in the event an oil spill occurs. Lisa hopes to begin her professional career in late 1996.

TUFFP Personnel Attend Training in Education Programs

In early June, Jerry Wilson and Charles Ingle attended the International SPE Conference on Environmental, Safety and Health in New Orleans. This meeting was invaluable in helping TUFFP continue its efforts to have all experimental test facilities in full compliance with accepted environmental protection and safety practices.

In late June, Marjel Hamlin attended a one week course offered by MacAcademy. When Marjel joined TUFFP in November as Administrative Assistant, her prior computer training was with PC's and not Macintosh computers. Attending this course gave her an opportunity for a period of intense training on Macintosh computer software used on a routine basis within TUFFP.

In late August, Jasmine Yuan will attend a one week training course in New Hampshire on the use of FLUENT. TUFFP has recently purchased this computational fluid dynamics software package for use in modeling flow behavior in the horizontal well project. The educational purchase arrangement for FLUENT requires us to provide training for two persons. At a later date, Cem Sarica will attend a similar training course.

TUFFP Financial Status Excellent

TUFFP's projected reserve fund balance at the end of 1996 is approximately $150,000. This figure is based on the assumption that $72,000 in unpaid membership fees for 1994 and 1995 from two member companies will be paid in 1996. At the present time, 5 member companies have not yet paid their membership fees for 1996.

A concerted effort has been made to contain research expenditures during 1996 until the past membership fee uncertainties are removed. Part of the expenditure reductions were possible as a result of the continuing opportunity to share salary and related expenditures with the Paraffin Deposition JIP.

Invoices for 1997 membership fees will be sent to member companies in late October to accommodate those companies who prefer to pay 1997 membership fees from their 1996 budgets.

1996 TUFFP Questionnaire

The 1996 TUFFP Questionnaire was distributed to the official Advisory Board representative with this newsletter. Members were asked to express their relative interest on existing and possible future research projects. A request was made that the questionnaire be returned by September 30, 1996. Results will be tabulated and summarized in the November Advisory Board meeting brochure.

TUFFP Membership Remains Stable

At this time, it appears that TUFFP membership will remain essentially constant for 1997. An interest in considering membership has been expressed by AGIP, the University of Petroleum in China, and Alberta Energy Company. However, notification has been received that ECOPETROL and Norsk Hydro will terminate their membership in TUFFP for 1997. A list of 1996 members appears on a following page.

TUFFP Acknowledges Part-time Student Work Contributions

Once again, a significant amount of support help on various research projects for TUFFP and the Paraffin Deposition JIP has been provided by students who are hired part-time during the academic year and full time during the summer. Typical activities include: oil field roustabout work; electronic wiring; assisting graduate students and research associates with data acquisition; and even machine shop work in the case of one student. Students involved are listed under TUFFP Staff in this newsletter.

Student Workers: Norhisham Safiin, Thad Andrews, Khairul Ahmad, Robert Marcano, John Jordan, Ahmad Muda, Hezri Mohd-Nor, Akmal Mohd-Badawi, Brandon Land, Jose Flores, and Bazlee Matzain

TUFFP Has New Home Page

A new TUFFP Home Page has been created on the Internet and can be accessed using the URL http://ffp6.ncp.utulsa.edu. The Home Page includes hyperlinks to several TUFFP topics and also to the Paraffin Deposition JIP. Other hyperlinks lead to The University of Tulsa and the Petroleum Engineering Department. Liming Zhu, a Computer Science M.S. student funded by the Paraffin Deposition JIP, developed and will maintain the Home Page. Member companies can receive up-to-date information on the general status of TUFFP and related JIPs. The Home Page could also be helpful in attracting new members and recruiting graduate students.

1996 TUFFP Members

Amoco Production Company
Arabian Oil Co., Ltd.
ARCO Oil and Gas Company
British Gas Corporation
BP Exploration
Chevron Petroleum Technology Company
Conoco, Inc.
ECOPETROL/Instituto Colombiano del Petroleo
Elf Aquitaine
Exxon Production Research Company
Institut Francais du Petrole
Institute of Oil & Gas Production Technology
Oil & Natural Gas Commission
Instituto Mexicano del Petroleo
INTEVEP
Japan National Oil Corporation
Mobil Research and Development Corp.
Norsk Hydro
Pertamina
Petrobras
Petronas
Saudi Arabian Oil Company
Shell Internationale Petroleum MIJ B.V.
Simulation Sciences
Texaco
TOTAL
UNOCAL

Calendar for 1996 and 1997 Two-Phase Flow Technical Meetings

1996

Sept. 23 - 24	Paraffin Deposition JIP Joint Committee Meetings, Tulsa, Oklahoma
Oct. 3 - 4	Paraffin Deposition Advisory Board Meeting, Tulsa, Oklahoma
Oct. 6 - 9	SPE Annual Technical Conference & Exhibition, Denver, Colorado
Oct. 23 - 25	28th Annual PSIG Meeting, San Francisco, California
Nov. 17 - 22	1996 International Mechanical Engineering Congress & Exposition (IMECE), Atlanta, Georgia
Nov. 18 - 20	SPE 2nd International Conference and Exhibition on Horizontal Well Technology, Calgary, Alberta, Canada
Nov. 20	TUALP Advisory Board Meeting, Tulsa, Oklahoma
Nov. 21	TUFFP Advisory Board Meeting, Tulsa, Oklahoma
Nov. 22	TUSTP Advisory Board Meeting, Tulsa, Oklahoma

1997

Jan 7 - 10	International Symposium on Lubricated Transport of Viscous Materials, jointly sponsored by: The International Union of Theoretical and Applied Mechanics (IUTAU) and the Caribbean Congress of Fluid Dynamics, Tobago
Jan. 28 - 30	Energy Week, Houston, Texas
March 9 - 11	SPE Production Operations Symposium, Oklahoma City, Oklahoma
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
April 24	Paraffin Deposition JIP Advisory Board Meeting, Tulsa, Oklahoma
May 5 - 8	Offshore Technology Conference, Houston, Texas
June 18 - 20	BHRGroup 8th International Conference - Multiphase 97, Cannes, France

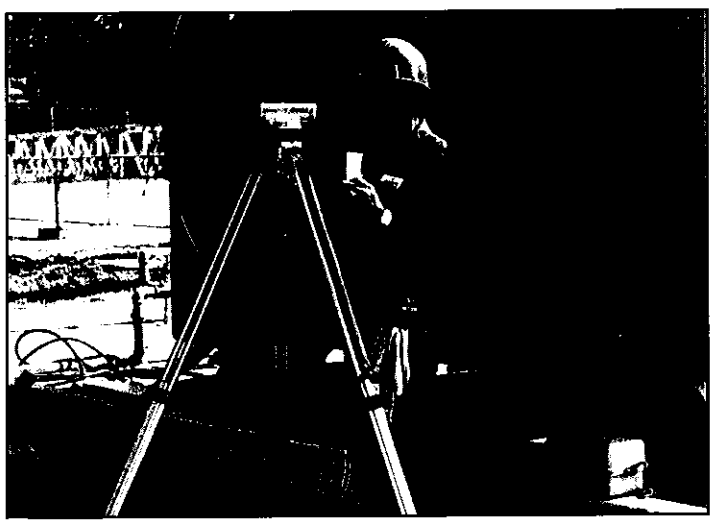
Status Report

Paraffin Deposition JIP Update

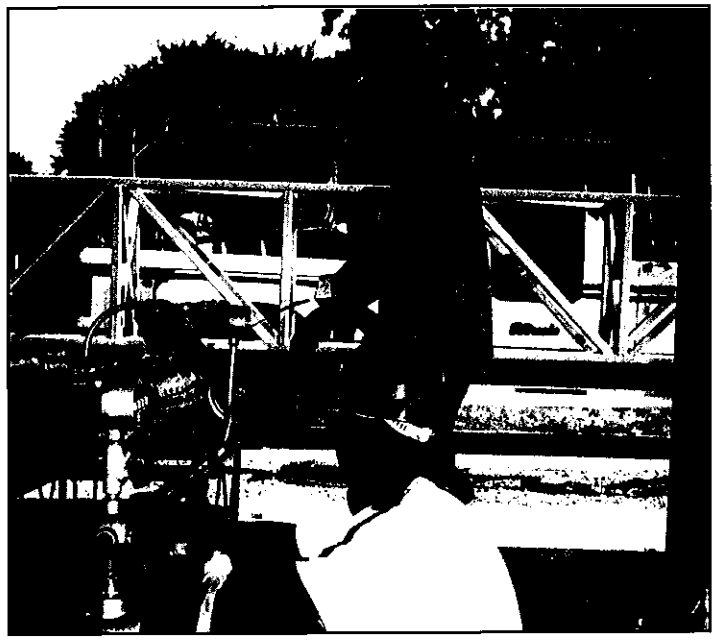
Paraffin deposition in oil and gas production systems is a major economic deterrent to the development of fields in deep water or cold climates. Paraffinic hydrocarbon liquids, including both crude oils and condensates, will form a paraffin or wax solid phase when the temperature falls below the cloud point of the liquid. Once formed, the wax will either be transported with the liquid (and gas) or will deposit on the pipe wall.

Many major oil companies have wax deposition prediction capabilities for single phase, stabilized oil conditions. These predictive capabilities are often based on laboratory tests in very small diameter conduits and results may not be valid for large diameter single phase export pipelines. The technology for predicting paraffin deposition under multiphase flow conditions in pipelines or wellbores is virtually nonexistent. The effects of multiphase flow variables on wax deposition rates and wax deposit composition must be investigated and correlated with single phase liquids. These multiphase flow variables include water cut, pipe inclination angle, flow pattern, gas and liquid velocities and liquid holdup. The impact of wax deposition on pressure drop (pipe roughness and/or diameter reduction) and flow rate also needs to be addressed.

A large Joint Industry Project 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, 4-year project is funded by membership fees from 27 domestic and international oil and gas companies, DOE, GRI and the US 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.



Howard Rettig checks grades on new construction.



Hezri and Akmal hooking up instruments on ARC Loop

Monitoring of progress in the JIP is accomplished through frequent committee meetings, quarterly reports and semi-annual Advisory Board meetings. A joint meeting of three of the technical committees is scheduled for September 23-24 and the next Advisory Board meeting will be held October 3-4. Both meetings will be held in Tulsa. The purpose of this update is to describe progress made in the JIP since the last TUFFP Advisory Board meeting on May 15, 1996.

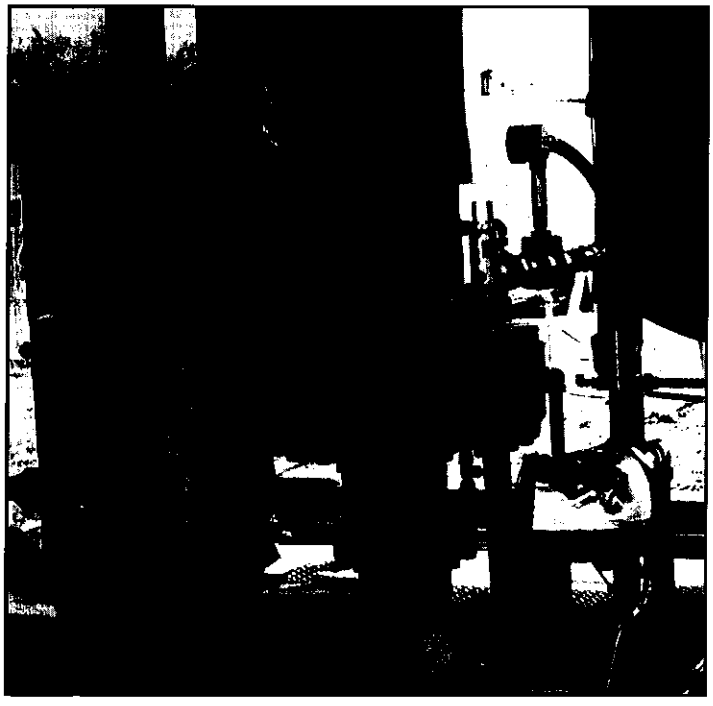
Mobil's South Pelto crude oil samples arrived in Tulsa last spring and characterization and PVT analyses of both separator oil and stock tank oil samples are underway via contract with Marathon Oil Co. Shell's Garden Banks condensate has recently arrived in Tulsa and both separator and stock tank condensate samples will soon undergo characterization and PVT analyses by Marathon. Both samples were selected by the JIP committees on the basis of rigid selection criteria, and 40 bbl of each sample are now at The University of Tulsa ready for paraffin deposition tests.

Exhaustive critical literature searches were completed in the areas of multiphase heat transfer and thermodynamics.

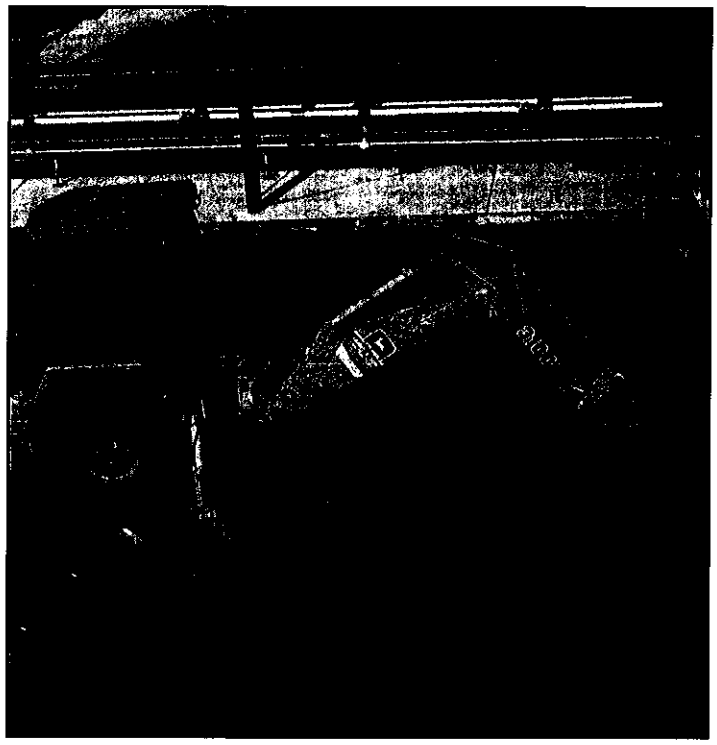
The heat transfer search was performed under a contract issued to Oklahoma State University and the thermodynamics search was conducted at The University of Tulsa. Reports on both studies have been distributed to JIP members. A computer program developed by Conoco that combines thermodynamics, heat transfer, fluid mechanics and deposition phenomena for single phase flow of waxy crude oils or condensates was made available to all JIP members by Conoco at a cost of $2,000. Distribution of the computer program and documentation manual is currently in progress.

A 1.7-in. diameter, 100-m long single phase flow test facility was transported to The University of Tulsa from Edmonton, Alberta, Canada in November 1995. This facility and support equipment have now been reassembled on newly prepared concrete slab areas and covered by large canopies. New equipment such as a chilling unit, heater, meters, pressure and temperature transducers, and data acquisition system have been purchased or donated and installed. The flow loop has now been charged with kerosene and preliminary tests are underway to perfect a procedure before actual tests begin in early September on the waxy crude and condensate. A building to house an instrumentation headquarters, offices and conference room is under construction and will be available in November.

Design of a new multiphase flow deposition flow loop is well underway. This loop will be constructed adjacent to the single phase flow loop and will feature test sections mounted on two booms that can be inclined to simulate flow in near-horizontal pipelines and wellbores. All concrete slabs, canopy cover, tower, booms and a compressor are already in place. Remaining design tasks will await analysis of preliminary single phase flow tests since decisions pertaining to the lengths of jacketed sections will affect many of the design variables. These lengths will depend in part on the rate of deposition anticipated and the distance from the beginning of the jacketed section where deposition begins. The multiphase flow facility should be operational by late spring.



Brandon Land dons hard hat to assist in loop construction



Contractor prepares site for instrumentation building under the watchful eye of Howard Rettig.

One student, Bazlee Matzain of Petronas in Malaysia, is currently working on the JIP and is pursuing an MS degree. He has also been authorized by Petronas to pursue a Ph.D. degree on the project. A visiting scholar, Emmanuel Del Case of France, will arrive in November to work on the project for a period of at least 12 months. He is fully supported by Elf Aquitaine. Hans-Jacob Lund will begin work on an M.S. degree in Petroleum Engineering this month and will work on the project. 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 much longer than those normally encountered in horizontal pipelines, often causing 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.

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, Tel-Aviv University, and Japan National Oil Corporation. This project is a major undertaking for all three investigating institutions and requires their combined expertise, experience and abilities. A total of five existing facilities will be utilized ranging in size from 20-m long 1 in. ID to 400-m long 4 in. ID with the operating pressures from atmospheric to 30 bars. Slug flow data acquired will be used for both model verification and the development of closure relationships.

Currently, fifteen major oil and gas companies have shown genuine interest in the project. We expect this number to reach twenty before the project starts. Also, a proposal has been submitted to the Oklahoma Center for the Advancement of Science and Technology (OCAST) to seek additional funding. The projected start date is January 1, 1997 and will be completed in three years. A new proposal is being prepared and will be mailed to potential participants in September 1996.

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

TUFFP and Paraffin Deposition JIP Staff

Executive Director . . . . . James P. Brill

Associate Director . . . . . Cem Sarica

Co-Principal Investigator -Paraffin . . . . . Mike Volk

Staff Engineer . . . . . Jerry F. Wilson

Research Associates . . . . . X. Tom Chen
Yehuda Taitel

Project Assistant . . . . . Marjel Hamlin

Administrative Secretary . . . . . Linda Jones

Technical Supervisor . . . . . Charles Ingle

Technicians . . . . . Tony Butler
Howard Rettig
Billy Smith

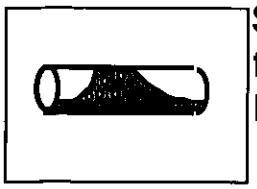
Research Assistants . . . . . José Flores
Hans-Jacob Lund
Robert Marcano
Bazlee Matzain
Weihong Meng
Nobutoshi Shimizu
Hong Yuan

Computer Resources Managers . . . . Brandon Land
Liming Zhu

Part-time Employees

Name	Major/Year	Origin
Khairul Ahmad	ChE/Post BS	Malaysia
Thad Andrews	ChE/Senior	USA
John Jordan	ME/Sophomore	USA
Free Marcano	High School Student	Trinidad
A. Mohd-Badawi	PE/Junior	Malaysia
Hezri Mohd-Nor	EE/Junior	Malaysia
Ahmad R. Muda	PE/Junior	Malaysia
Dan Pickett	PE/Freshman	USA
Norhisham Safiin	PE/Junior	Malaysia
Lisa Takagi	PE/Post BS	USA

Research Progress



Slug Characteristics for Two-Phase Horizontal Flow

Following is the abstract in the final report on this project. The report is scheduled for distribution in September 1996.

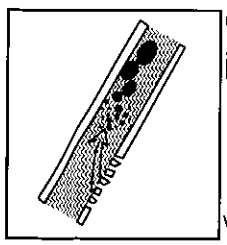
ABSTRACT

Understanding the behavior of multiphase flow in pipelines is an important factor in the safe and economical design and operation of multiphase pipelines. Slug flow is a common and very complex occurrence in these pipelines.

An existing test facility was modified to conduct horizontal slug flow experiments. Sixty-two tests were conducted over varying combinations of gas and liquid flowrates. A total of 25,975 slugs were generated, ranging from 23 to 1145 slugs per test.

Analysis of the data showed that the slug length distribution followed a Lognormal pattern. New correlations were developed for slug liquid holdup, film liquid holdup, slug translational velocity, slug frequency, average slug length and design slug length.

Using the data from this study the new correlation for slug liquid holdup was compared with predictions from the correlations of Gregory et al. and Yang. Similarly, the new correlation for slug frequency was compared with the correlation of Hill and Wood. This correlation performed better than Hill and Wood on this data set. As expected the new correlations performed best on the founding data set. The new correlation for slug translational velocity is in good agreement with the findings of other investigators.

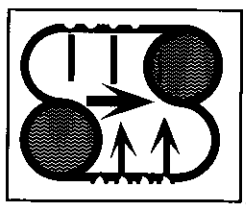


Oil-Water Flow Patterns in Vertical and Deviated Wells

The simultaneous flow of oil and water in wells is a significant oil field occurrence that has received little attention in the technical literature. Application problems associated with the identification of oil-water flow patterns in wellbores include interpretation of production logs, pressure drop calculations, downhole metering and design and modeling of artificial lift installations. The objectives of this research project include acquiring experimental data at various flowing conditions and inclination angles, typical of vertical and deviated producing wells, describing and classifying the observed flow patterns and developing mechanistic models to predict the flow pattern transitions.

The experimental research approach was extensively discussed at the May 1996 Advisory Board meeting. In recent months, work has concentrated on preparing the test apparatus and acquiring experimental data. The ambitious experimental program will include collecting over 600 data points for inclination angles of 45°, 60°, 75° and 90° from horizontal. Data acquisition includes measurements of pressure, differential pressure, temperature, holdup and conductivity of the flowing fluids using special probes designed for use in this research project. In addition, excellent video tapes are being recorded to capture details of the flow patterns. A preliminary analysis of the data acquired so far suggests that, as expected, the extrapolation of Scott's flow pattern data (15° and 30°) to higher inclination angles is not appropriate. A new systematic oil-water flow pattern classification for vertical and deviated wells will be introduced as part of this study.

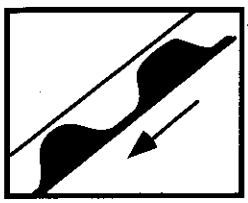
Activities planned for the coming months include completing the extensive data acquisition program, followed by data analysis and modeling tasks. Results will be presented at the November Advisory Board meeting.



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.

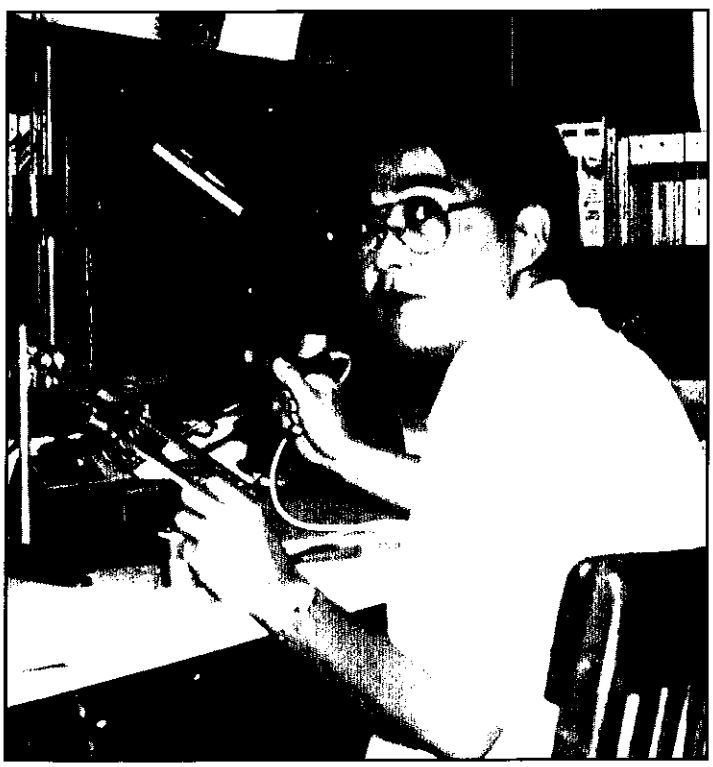
In the second phase of this project, the flow behavior in horizontal wells with uniform fluid injection from multiple perforations is being investigated. Acquisition and processing of data have been completed for 1.0 in. diameter pipe perforated with 5, 10 and 20 shots per foot (geometrically similar to 6.0 in. diameter casing perforated 1, 2 and 4 shots per foot). Data analysis is currently underway. The CFD software package FluentTM will be used when analyzing the data. We are in the process of obtaining this software and also a new 120mhz model C110 HP workstation that will be necessary to use FluentTM. Jasmine Yuan will attend a one-week FluentTM training session in August 1996.



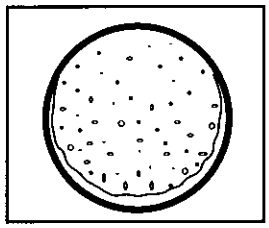
Slug Dissipation in Downward Flow

Slug flow is a common occurrence in hilly terrain pipelines. The standard engineering method has been to divide the pipeline into various sections of constant slope, 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.

A simple mechanistic model has been developed to predict the slug dissipation velocity as well as the slug dissipation distance, and a literature survey has been completed. An existing inclined flow facility is being modified for this study. Currently, modifications of the inclined flow test facility are underway, including installation of 12 new capacitance sensors. Data acquisition will start in September after the modification of the test facility is completed. It is anticipated that a significant portion of the experimental work will be presented at the November Advisory Board meeting.



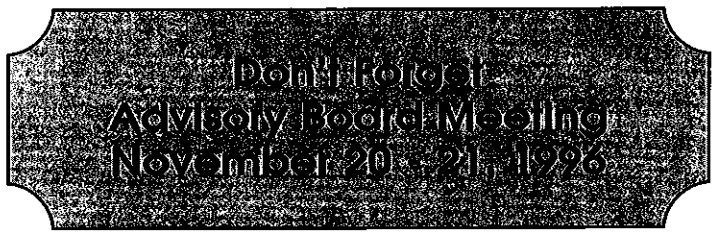
Nobutoshi Shimizu assembly of capacitance sensors

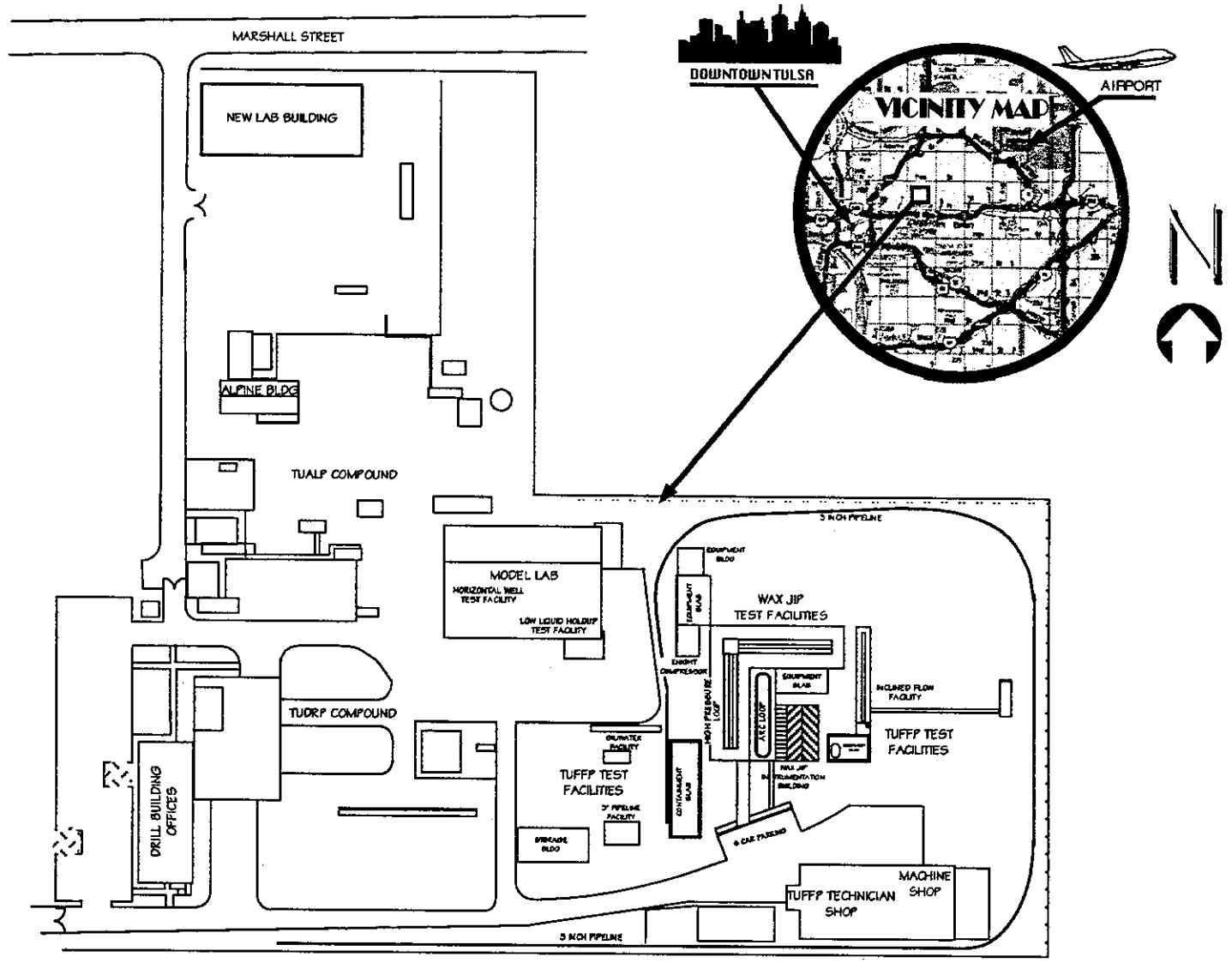


Low Liquid Loading Two-Phase Flow In Near-Horizontal Pipelines

Gas-liquid two-phase flow with small amounts 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 significant increase in pressure loss compared to single phase gas flow. Despite numerous theoretical and experimental investigations into gas-liquid pipeline flow, only a few studies on low liquid loading two-phase flow have appeared in the 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. All previous publications on low liquid loading two-phase flow in pipes have been collected and reviewed. Extensive experimental studies will be conducted with a new TUFFP test facility to be constructed in the Model Lab building on the North Campus of The University of Tulsa. The new facility design is nearing completion and construction will begin after dismantling the two-phase splitting facility on the same site. Compressed air and a highly refined oil will be used as testing fluids in this study. Both stratified-wavy and annular flows, the most common flow patterns encountered in gas pipelines, will be studied. Liquid film thickness distribution around the pipe wall will be measured using a newly developed TUFFP capacitance probe. 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 closure relationships will be developed.





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