THE UNIVERSITY of TULSA

TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

WINTER 1994 | A Semiannual Publication | Volume 8, Number 3

TUFFp Talk

TUFFP Hires Project Assistant

TUFFP recently selected Elissa Wise as project assistant. This new position is intended to provide broad administrative and secretarial support for TUFFP. As project assistant, Ms. Wise will produce newsletters and technical documents, coordinate conferences, and work closely with staff to ensure efficient communications and office operation.

Ms. Wise has extensive experience in administrative support of engineering and technical efforts in the energy and transportation industries. Her expertise includes skills in technical writing, desktop publishing, presentations, document control, cost control, and scheduling.

A native Tulsan, Elissa is a graduate of Oklahoma State University. Her hobbies include reading, aerobics, and camping.

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Brill Receives Two SPE Awards

At the SPE Annual Technical Conference and Exhibition in New Orleans, La., September 25-28, 1994, Dr. Brill received both the SPE Production Engineering Award and the SPE Distinguished Achievement Award for Petroleum Engineering Faculty.

For the Production Engineering Award, he was "recognized for more than 25 years of outstanding accomplishments as an educator and author in multiphase flow behavior; for contributions that optimized oil and gas well and transmission pipeline design; and for ongoing commitment to enhancing industry knowledge through committed service to the Society."

The faculty award was established to recognize superiority in classroom teaching, excellence in research, and significant contributions to the petroleum engineering profession. The plaque received states "For his personal standards of professionalism and service that have particularly benefited the Society of Petroleum Engineers, the petroleum engineering profession, the petroleum industry, and the quality of petroleum education; for his long, active career as researcher and educator; and especially for his excellence in teaching and his counseling with current and former students."

Progress Continues on GRI Project

Work resumed in September 1994 on the GRI research project on PCB migration in gas transmission and distribution systems. Activity on this project had been stopped on April 1, 1994, until a fully signed subcontract was in force with Penn State University. The decision to stop working on the project turned out to be a wise one since, when the subcontract arrived, GRI had authorized only about two-thirds of the anticipated funding. Since then, a significant effort has been expended to obtain high quality low-liquid loading data in the TUFFP 1,400-ft. long pipeline. More detailed progress is reported elsewhere in this newsletter.

The final report describing research conducted during 1994 will be submitted to GRI in early January. An industry PCB workshop will be held in Phoenix on January 30.

A proposal for future research to be conducted on this project will be submitted to GRI in early 1995. The proposal will concentrate on experimental data and closure relationship development for very low liquid loading cases.

Paraffin Deposition JIP Status

On November 18, 1993, Conoco and TUFFP hosted a joint industry workshop on the potential of forming a Joint Industry Project (JIP) to address the problem of wax deposition in flowlines and wellbores. Sixteen oil companies participated in the workshop and expressed a need to develop this technology. Working together, Conoco and TUFFP combined a scope of work, objectives, deliverables, timetable, and cost estimates into a pre-proposal that was mailed to a large number of organizations in June 1994. Several meetings have been held with BDM Oklahoma, Inc., NIPER, and University of Tulsa personnel to determine the probability of obtaining partial funding of the study by DOE. Similar communications have occurred with GRI.

A meeting of potential JIP participants for the proposed study was held September 1, 1994, in Tulsa, Okla. In attendance were 38 professionals from 23 organizations. Eight additional companies were interested in the project but were unable to attend the meeting. After the technical discussions were complete, a poll of the 23 organizations to assess interest in funding the JIP yielded 18 yes, 5 undecided, and 0 no votes. Based on this support, two committees were formed to recommend revisions to the pre-proposal, a Preliminary Technical Advisory Committee and a Preliminary Administrative Advisory Committee. These committees met in Houston, Texas, on September 23 and again on November 2 in Tulsa, Okla., to revise the pre-proposal.

The proposal for "Paraffin Deposition Prediction in Multiphase Flowlines and Wellbores" was mailed worldwide on December 1, 1994. The proposal describes a four-year, 3.3 million-dollar study to develop an integrated model for the prediction of paraffin deposition in two-phase (gas/oil) production systems.

The target date to formally establish the JIP is January 1, 1995, but the actual commencement date will be after the 19th JIP participant executes the Letter of Agreement.

It now appears that DOE and GRI will each pay for approximately 25 percent of the total cost of the research project. Each company joining the JIP will pay a total of $90,000 over the four years with annual fees of $30,000, $30,000, $20,000, and $10,000 for 1995, 1996, 1997, and 1998, respectively.

The paraffin deposition project will require a synergistic effort to combine improved technologies in thermodynamics, heat transfer, and multiphase flow through pipes. At this time, it appears that most of the heat transfer portion of the project will be subcontracted to other organizations. It also appears that most of the thermodynamic research will be conducted by a chemical engineering faculty member at The University of Tulsa working with a new Ph.D. student. The multiphase flow research will be conducted in part by current TUFFP personnel

and in part by a new post doctoral research associate and a new Ph.D. student. An advertisement to fill the research associate and Ph.D. positions will appear in technical journals in the near future. One part of the paraffin deposition research program will involve screening and improving existing single-phase flow deposition models using new experimental data that will be obtained using a waxy crude and a waxy condensate. This research topic could be assigned to Bazlee Matzain, a master's degree candidate in petroleum engineering sponsored by PETRONAS.

Caracas Symposium Includes Multiphase Flow Topics

A special symposium on "Rheology and Processing of Hydrocarbons" will be held in conjunction with the Third Caribbean Conference on Fluid Dynamics at the University of Simon Bolivar in Caracas, Venezuela, February 5-8, 1995. This special symposium will include several presentations on both multiphase flow and the flow of waxy crude oils. Preliminary plans call for approximately 16 presentations on February 8, with an opportunity to engage in further conversations and observe research facilities at INTEVEP, the research affiliate of PDVSA on February 9. The symposium is being chaired by Dr. Dan Joseph, professor of aerospace engineering and mechanics at the University of Minnesota, and Dr. Brill.

TUFFP Suffers Membership Decline

Five companies informed TUFFP that they would terminate membership at the end of 1994. Termination notices were received from Chiyoda Corporation, JGC Corporation, Marathon Oil Company, NKK Corporation, and Phillips Petroleum Company. Discussions continue with several companies that are considering membership in TUFFP for 1995. A list of 1994 members appears on a following page.

Fluid Flow Friends

Over the past few years, several companies and individuals have assisted TUFFP with donations and/or substantial discounts on major equipment items. We would like to take this opportunity to recognize these firms and individuals so our member companies will be aware of their contributions.

One of our most significant contributions has come from NATCO, courtesy of Mr. Dwight Faulkner in Houston, Texas. When we were designing the new Down Flow Facility, Mr. Faulkner promptly shipped a separator for the new facility, making a major impact on commissioning of this facility. When we approached Mr. Faulkner regarding our needs for the new Oil/Water Test Facility, again NATCO offered a state-of-the-art separator and coalescent filter. These major contributions to our test facilities had a major impact on completion time and cost. Many thanks to NATCO and Mr. Faulkner.

When TUFFP had need for an accurate surveying instrument, Mr. Morris Dundee with Practical Engineering in Tulsa, Okla., donated a Wilde T3 surveying instrument for our use. This is a very accurate instrument for measuring inclination angles in our Down Flow Facility and will give us many years of excellent service. Mr. Glen Reid with Hewlett Packard Company was instrumental in approving a substantial trade-in allowance and discount on our new HP Workstation.

Another firm that has consistently come to the rescue is Frank W. Murphy Mfg. in Tulsa. Mr. Mike Murphy has provided numerous controls for separators, air compressors, and other facilities. A big TUFFP Hurricane Hooray for Mike and Murphy Mfg.!

A major contractor, friend of TUFFP, and a supplier that we frequently call upon for many of our unique projects is BLM Equipment and Manufacturing in Catoosa, Okla. BLM was the general contractor on our Down Flow Facility and has provided support work on the Oil/Water Facility, the Centennial Clean Up of the North Campus (removing old unused towers), and renovation of storage tanks and separators. Carl Bence, Eddie Michels, and Tom Henry's competitive bid prices have considerably enhanced the feasibility of many test facilities.

A number of our suppliers have given us major discounts on test equipment and also offered advice. Mr. Max Kopp with Validyne Corp. has provided discounts and considerable expert advice on pressure transducers. D. J. Shubeck helped design the new Moyno pumps for the Oil/Water Facility. Their discount on the pumps enabled us to size pumps for future expansion of this major test facility. Mr. Martin Mabry with Fisher-Rosemount Micromotion has spent many hours assisting us with flow meters and calibration software, and authorized major discounts. Mr. Joe Martin with Aberdeen Dynamics in Tulsa provided assistance with our winch and hydraulic system on the Down Flow Facility. Mr. Richard Cadille with Kistler Instrument Corporation in Amherst, N.Y. authorized a substantial educational discount on piezometric pressure transducers for the new Oil/Water test facility. Mr. Ed Moore and Ms. Sharon Bell with Vinson Supply in Tulsa have donated numerous instruments and have been very supportive friends of TUFFP. The new Oil/Water facility utilizes several of these donated instruments.

TUFFP personnel make full use of the Oklahoma Department of Central Services Property Distribution Division in Oklahoma City, Okla. Numerous items have been obtained from this agency that have greatly reduced our construction and operating costs. This agency obtains surplus property from numerous Federal and State agencies for redistribution at very reasonable costs. Mr. Joe Burlison, now retired, provided very helpful and supportive information when we had specific needs. The Phillips Petroleum Company's Investment Recovery Center in Bartlesville, Okla. also provided numerous items at very reasonable costs. Mr. Robert Weber has been very helpful in locating items from the Phillips facility.

The firms and individuals mentioned above had a major impact on the cost-benefit ratio of our research facilities. Our purpose in mentioning these firms is to encourage TUFFP members to thank these Fluid Flow Friends.

TUFFP Schedules 1995 Short Course

The TUFFP short course "Two-Phase Flow in Pipes" is scheduled to be taught again in Tulsa, Okla., at the Doubletree Hotel at Warren Place May 15-19, 1995. A brochure advertising the course will be mailed to TUFFP members in early 1995.

Once again, the course will be taught by Dr. Brill and Dr. Cem Sarica. The purpose of this course is to give participants a well-grounded understanding of the fundamentals of two-phase flow through pipes and restrictions. Completed and current TUFFP 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.

The same pricing schedule that was used for the 1994 TUFFP course will be retained for 1995 and is given below.

TUFFP Member Companies	
Per Person	$950
Group Discount - Per Person	$850
Non-Member Companies	
Per Person	$1,445
Group Discount - Per Person	$1,195

Members can enroll by contacting the Continuing Education Department at The University of Tulsa, (918) 631-2347, sending a fax to (918) 631-2154, or sending a telex to 4977543.

TUFFP Participates in Several Technical Conferences

Papers based on TUFFP research have been submitted to various technical meetings since the last newsletter. In addition, TUFFP personnel are involved in planning for several conferences that will include sessions on multiphase flow through pipes. Following is a summary of these activities.

- Dr. Brill is serving as a corresponding member for the BHRG Multiphase 95 Conference in Cannes, France, June 7-9, 1995.
- Dr. Sarica is to present "Experimental Analysis of Induced Two-Phase Flow Transients in Horizontal Pipelines" co-authored by F. Vigneron, EDF, GDF, Dr. Sarica, and Dr. Brill, at the BHRG conference in Cannes.
- Jose Luis Trallero will present the paper "Non-Emulsified Oil-Water Flow Patterns in Inclined Pipes" for the 1995-SPE student paper contest organized by the local student SPE chapter.
- Dr. Brill will co-chair the Symposium on Rheology and Processing of Hydrocarbons in Caracas, Venezuela, February 8, 1995, and will make a presentation on Flow Pattern Transitions for Oil-Water Flow.

BHRG Schedules Multiphase 95 Conference

Once again BHRG has scheduled a conference on multiphase flow through pipes. Their seventh biannual conference titled "Multiphase 95 - Where are we on the 'S' curve?" is scheduled for June 7-9, 1995, in Cannes, France. More than 50 abstracts were submitted for the conference and once again an outstanding collection of papers on multiphase flow through pipes will be presented.

TUFFP Transient Forum a Big Success

TUFFP sponsored a very successful forum on transient multiphase flow through pipes on Thursday, September 29, 1994, at the TEXACO offices in New Orleans, La. This date was chosen so that persons attending the SPE Annual Technical Conference and Exhibition in New Orleans, September 25-28, 1994, could include the Transient Forum during their travel plans. Thirty-seven persons from 16 member companies, six non-member organizations, and TUFFP attended the forum. Presentations were made by 12 individuals.

TUFFP Promotes Sarica and Chen

Effective September 1994, Dr. Cem Sarica was promoted to a position of research associate in the Petroleum Engineering Department with assignment to TUFFP. Dr. Sarica has also received labor certification and has applied for permanent residency in the United States. Cem served as a post-doctoral research associate for a period of two years prior to his promotion, working on a variety of projects dealing with modeling multiphase behavior. He also assisted Dr. Brill in supervising some of the TUFFP M.S. and Ph.D. students.

Dr. Xuanzheng (Tom) Chen will be promoted to a research associate in the Petroleum Engineering Department effective January 1995 with assignment to TUFFP. Tom has served as a post-doctoral research associate in TUFFP since April 1993 and has been very instrumental in helping conduct a variety of experimental research projects, assisting graduate students with acquisition and analysis of data, and modeling of multiphase flow behavior. Tom will also play an important roll in the new JIP to investigate paraffin deposition in flowlines and wellbores.

Advisory Board Meetings Scheduled

The next two Advisory Board meetings will be held on May 9-10, 1995, and tentatively November 15-16, 1995.

The May meeting will be held at the Doubletree Hotel at Warren Place in Tulsa, Oklahoma, and the November meeting will probably be held at the same hotel. Request for Information forms will be mailed to member companies approximately six weeks prior to each meeting to help determine attendance. The forms will be accompanied by information on hotel reservations and travel to and from the airport.

The May Advisory Board meeting will begin at 8:30 a.m. on Wednesday, May 10, and will adjourn at 4:30 p.m. A pre-meeting cocktail party will be held on the 19th floor of the adjacent Two Warren Place Building from 6:00 to 8:00 p.m. on Tuesday May 9. A tour of TUFFP test facilities will be conducted on Tuesday afternoon from 3:00 to 4:30 p.m.

These meeting dates were selected to accommodate persons who attend Advisory Board meetings of other cooperative research programs at The University of Tulsa. Following is a summary of the dates for May 1995.

Erosion/Corrosion	May 8
TUPREP	May 8
TUDRP	May 8-9
TUFFP	May 10
TUALP	May 11

TUFFP Advisory Board meeting brochures will be mailed to all members prior to the meeting. The brochures will contain sufficient information to help each attendee actively participate in discussions on current and future research projects, financial matters, and operating procedures. Brochures containing slide copy for all presentations will be distributed at the meeting but will not be mailed to members.

TUFFP Financial Status Remains Excellent

Official financial figures to close out TUFFP for 1993 are still not available, primarily due to The University of Tulsa changing to a new database system during 1994 and also not being able to transfer expenditures pertaining to the GRI project until a contract was in place. However, it appears that our previous estimate of a $112,248 reserve fund balance as of January 1, 1994, is valid. Current estimates also indicate that we will end 1994 with a reserve fund balance of more than $50,000. As a result, a decision was made that there would be no increase in TUFFP membership fees for 1995.

The University of Tulsa was successful in having a one-time line-item included in the U.S. Department of Energy (DOE) 1995 budget of $1.1 million allocated to TU as cost-sharing of existing and planned research consortia. It now appears that TUFFP's allocation from this amount will be $267,000 of which $200,000 will be used as DOE matching funds for the new paraffin deposition JIP. The remaining $67,000, will be used to further enhance TUFFP research activity and will partially offset the loss of membership income for 1995.

A budget for 1995 is under preparation and will be shared with member companies in early January 1995.

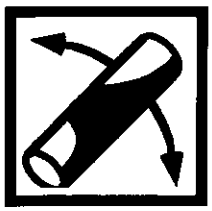
1994 TUFFP Questionnaire Results

The 1994 TUFFP Questionnaire was distributed to the official Advisory Board representative for each member company in August 1994 with a request that all results be sent to us by November 4, 1994. Responses were received from only 17 member companies and are tabulated below. Weighted totals are based on assigning a value of four for each very high vote, three for each high vote, etc.

Research Project	Level of Interest					
	Very High	High	Med	Low	None	Weighted Total
1. Flow Pattern Modeling of Oil-Water Flow in Inclined Pipes*	2	9	4	2	0	45
2. Modeling Gas-Oil-Water Flow in Pipelines	7	7	3	0	0	55
3. Two-Phase Flow in Hilly Terrain Pipelines	4	7	3	2	1	45
4. Critical Analysis of Data and Models for Predicting Two-Phase Flow Splitting at a Tee Junction	1	1	8	5	2	28
5. Low Pressure Transient Two-Phase Flow in Pipelines*	4	4	6	2	1	42
6. Slug Length Distribution and Liquid Holdup for Two-Phase Horizontal Flow*	5	9	1	1	1	50
7. Flow in Horizontal Wells*	4	7	4	2	0	47
8. Evaluation of Flow Pattern Transition Models at Elevated Pressures	3	5	5	4	0	41
9. Comprehensive Mechanistic Model for Predicting Downward Inclined Two-Phase Flow Behavior*	1	7	7	2	0	41
10. High Pressure Transient Two-Phase Flow in Pipelines	8	4	4	1	0	53
11. Comprehensive Mechanistic Model for Upward Inclined Two-Phase Flow in Wellbores	3	6	4	4	0	42
12. Flow Pattern Transition Modeling of Two-Phase Flow in Pipes*	4	4	8	1	0	45
13. Investigation of Low Liquid Holdup Flow in Pipelines*	3	4	7	1	1	40
14. Paraffin Deposition in Multiphase Pipelines and Wellbores	8	5	1	1	2	50
15. Churn Flow in Wellbores	0	4	5	6	2	28

* Current TUFFP research projects.

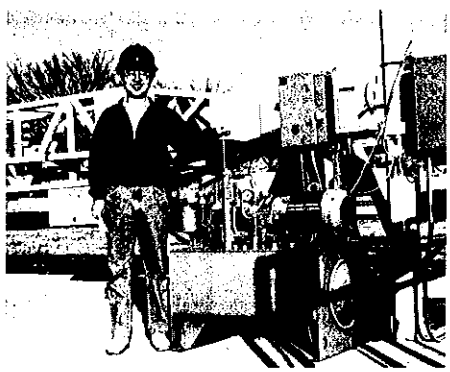
Research Progress REPORTS



Downward Two-Phase Flow in Inclined Pipes

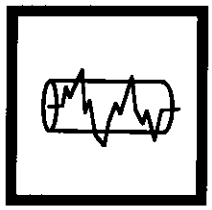
The downward simultaneous flow of gas and liquid is often encountered in hilly terrain pipelines and injection wells. Most of the methods for predicting gas-liquid two-phase flow characteristics (pressure drop, liquid holdup, etc.) have been developed for either upward vertical or upward inclined flow. The objective of this project is to study, experimentally and theoretically, two-phase flow in downward inclined pipes.

The first phase of the project, facility construction and preliminary data acquisition on downward, co-current, intermittent two-phase flow, has recently been completed. A series of two-phase intermittent flow experiments were conducted in a 2-in.-diameter, 65-ft.-long PVC pipe. The fluids used were air and kerosene. Based on the acquired data, little effect of inclination angle was observed on slug translational velocity and slug body liquid holdup for inclination angles from 0° to -30°.



In the second phase of this project, additional downward co-current intermittent two-phase flow data will be acquired for the entire range of downward inclination angles. Slug flow characteristics will be thoroughly studied using the acquired data. Mechanistic models will be developed for downward intermittent flow characteristics.

A redesign of the test facility has been completed based on experience from commissioning the test facility and data acquisition and data processing during the first phase of the project. With the new design, the slug flow development length will be longer and data acquisition speed and duration will be significantly improved with a more powerful computer. Also, efforts have been made to obtain better slug front information through better arrangement of pressure transducers. Mechanistic modeling of downward co-current intermittent flow is underway.



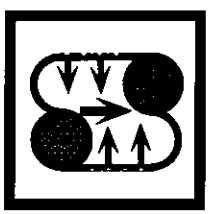
Transient Two-Phase Flow in Horizontal Pipelines

The objective of this study is to investigate experimentally transient two-phase flow phenomena in horizontal pipes and compare the acquired data with predictions of available transient two-phase flow simulators such as OLGA, PLAC, and a TUFFP simplified transient code.

An experimental program has been carried out to acquire two-phase transient flow data on a 420-m (1,378-ft.) long, 77.9-mm (3.068-in.) diameter horizontal pipeline. The existing test facility was modified for this study. A new generation of capacitance sensors was developed to measure the liquid holdup. A Macintosh-based data acquisition system was used to acquire and monitor the data simultaneously.

The experimental runs comprised gas and liquid flow rate changes, pipeline start-up with different initial conditions, and liquid blow out tests. The initial and final steady-state flow patterns for these transient tests were stratified and slug flow. Measured parameters included inlet gas and liquid flow rates, outlet liquid flow rate, absolute pressure and differential pressures, temperature, and liquid holdup.

The analysis of the experimental data revealed some of the propagation characteristics of the induced transients for different initial and final steady-state flow patterns. The experimental data also showed that a change in inlet gas flow rate could create fast transients, inducing a temporary intense slugging at the pipeline outlet, while transients induced by a liquid flow rate change at the pipe inlet were slow and smooth. All of the simulator runs are complete for the corresponding experimental tests. A final report will be mailed to member companies in late January 1995. Detailed evaluation of the results will be presented at the next Advisory Board meeting.

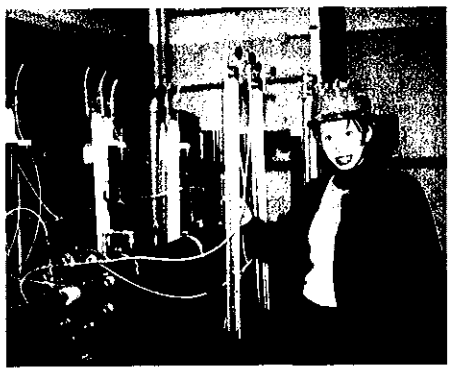


Flow Behavior in Horizontal Wells

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.

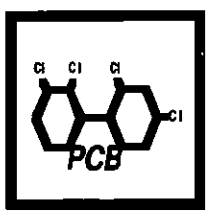
A survey of the literature reveals that no experiments have been conducted for relatively low Reynolds numbers in perforated horizontal pipes with fluid injection. The objective of

this project is to investigate, experimentally and theoretically, flow behavior in horizontal wells.



In the first phase of this project, the flow behavior in a pipe with a single perforation has been investigated. Experiments have been conducted for no-injection and for influx to main flow rate ratios varying from 1/5 to 1/100. Friction factors calculated from the no-injection data cases have been compared with friction factors calculated by the Blasius formula and showed a fairly good agreement. The data acquired with fluid injection have been analyzed and a preliminary friction factor correlation has been developed. The evaluation of the correlation is being carried out by comparing the correlation predictions with other available data, such as Asheim's.

Different removable test sections have been built for three pipe perforation densities. The second phase of this project, multiple entry experiments, will be started in late November.



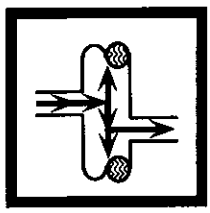
Liquid Transport in Gas Transmission Pipelines

The initial part of this research project, completed in January 1994, essentially involved qualitative studies on the mechanisms of liquid transport under low-liquid holdup two-phase flow. Experiments were conducted on the TUFFP 3-in.-diameter, 1,400-ft.-long horizontal pipeline. A significant new contribution was the investigation of the two-phase flow behavior in a transparent valley section of the pipeline. The results were presented at the last Advisory Board meeting.

With a more clear understanding of the physical phenomena, we have now conducted semi-quantitative tests on the 3-in. flow loop in order to evaluate two transient phenomena: (*i*) increase of the liquid flowrate and (*ii*) increase of the gas flowrate. Experimental results were compared with those obtained from OLGA and PLAC, two commercial transient simulators. Results indicate that the numerical simulators can reproduce the occurrence of the transients; however, prediction of the liquid holdup values and the transient velocities were, in most cases, poor. Experience indicates that the most likely weakness in the transient simulators is the lack of appropriate constitutive relationships for parameters such as the interfacial friction factor at very low liquid holdup conditions.

For the remainder of the year, we are concentrating on more detailed quantitative experiments at very low liquid flow rates, on the order of 0.3 to 0.5 gallons per minute. Early next year, we will decide on the additional measurement devices required to obtain even lower liquid flow rate data, close to liquid loading values observed in the field. The ultimate goal will be to provide constitutive relationships that can be incorporated into a transient simulator to produce more realistic results.

This research project is being sponsored by the Gas Research Institute. Dr. Michael Adewumi from Penn State University and Dr. Brill serve as co-principal investigators. TUFFP member companies were asked in the 1994 Questionnaire to express their relative interests in this project.

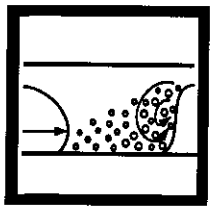


Two-Phase Flow Splitting at a Reduced Tee Junction with an Inclined Side Arm

The objective of this study is to investigate, experimentally and theoretically, two-phase flow splitting at a reduced side-arm tee junction for horizontal, upward, and downward inclinations of the side arm. The study is restricted to the stratified-wavy flow pattern upstream of the tee junction.

The data acquisition phase has been completed. Experimental data have been acquired for side-arm branches that are horizontal, have downward inclinations of 5°, 10°, 25°, 40°, and 60°, and have upward inclinations of 1°, 5°, 10°, and 20° from the horizontal. The data reveal that, for the case of a downward side-arm branch, the high gas velocity in the branch and gravity effects tend to increase the liquid flowing into the branch as compared to the horizontal run arm. For the case of upward inclination angles, gravity forces tend to reduce liquid flow into the branch. Consequently, as the inclination angle increases, less and less liquid is observed in the branch for the same gas split ratios.

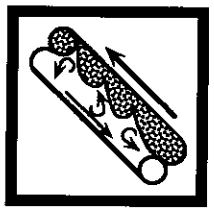
Currently, an attempt is underway to modify the model developed for the regular tee junction by Penmatcha (1993) for the case of a reduced tee junction. The final report on this project will be submitted at the May 1995 Advisory Board meeting.



Two-Phase Slug Flow in Pipelines

Slug flow is the most common flow pattern in multiphase transportation pipelines due to the long distances, large diameters, and uneven elevation profiles frequently encountered. Slug flow exists over a relatively wide range of gas and liquid flow rates, and over the entire range of pipe inclination. The maximum possible slug length and liquid holdup in slugs are of particular importance to the design of multiphase transportation pipelines and downstream processing units. However, issues still remain unresolved. The objective of this project is to conduct a large number of extended time duration tests over the entire slug flow pattern region in the TUFFP 1,400-ft.-long pipeline. This will enrich the existing TUFFP slug flow data bank and make it possible to develop improved models for the prediction of slug length distribution and liquid holdup.

Modification of instrumentation and the data acquisition system has been completed. All instruments have been calibrated. The extended time duration data acquisition is underway. About 100 tests, covering the entire slug flow pattern region, will be conducted. More than 200 liquid slugs will be sampled for each test. The experimental characteristic parameters include slug length, liquid holdup profile along the slug body, slug translational velocity, pressure drops in the slug body and the liquid film zone, respectively, and the total pressure loss during slug flow. The results will be presented at the next Advisory Board meeting.



Non-Emulsified Oil-Water Flow Patterns in Inclined Pipes

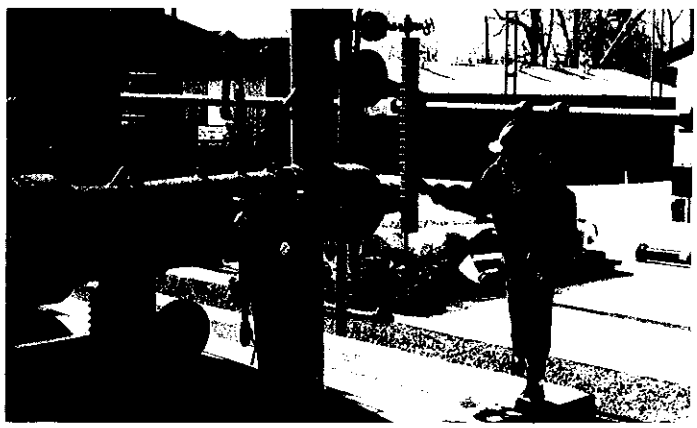
The need for reliable design methods has been the driving force behind a very large research effort in two-phase gas-liquid flow over the past 30 years. Recently, the industry has turned its attention toward understanding the simultaneous flow of gas-oil-water mixtures. However, the limiting case when no gas phase is present has received inadequate attention. The flow structure of oil-water mixtures in pipes is quite different from that of gas-liquid mixtures. Therefore, gas-liquid flow studies cannot readily be applied to oil-water systems. The objective of this study is to understand and predict the limiting case of non-emulsified, oil-water flow patterns in near-horizontal pipes. The scheduled inclination angles for the tests are 0°, ±0.5°, ±1°, ±2°, ±5°, ±10°, and ±15°, which correspond to typical pipeline operational conditions. No experimental data have been reported before for inclination angles of ±0.5°, ±1°, ±2°, ±5°, or ±10°.

Construction of the new versatile gas-oil-water test facility is underway. All civil engineering work (concrete and containment slabs) is complete. A new 440 volt power line for the main pumps is being installed. All major equipment will be set by November 14 in order to start the plumbing and electrical work. Construction of the facility is expected to be finished by February 1995.

A mechanistic approach, based on physical phenomena, will be used to model the oil-water flow pattern transitions. Mass and heat transfer will not be considered. The flow pattern transitions modeling will be divided into two major regions: separated flow and dispersed flow. Separated flow is defined

Ted Hope from the College of Engineering and Applied Sciences assists with the placing of the liquid storage tanks manufactured by BLM Equipment & Mfg. Co., Inc.

as the flow pattern where both phases are continuous in the axial direction. When the continuity is lost in either phase, the flow pattern is described as dispersed flow. Dispersed flow includes O/W (evenly distributed oil dispersed in a continuous water phase), W/O (evenly distributed water dispersed in a continuous oil phase), and any other flow structures that have one of the phases distributed in drops or slugs, with or without radial gradient concentrations.



Jose Luis inspects the coalescing filter donated by Natco courtesy of Mr. Dwight Faulkner.

A two-fluid model will be used to predict the transition from separated flow to dispersed flow. Analysis will concentrate on the stratified/non-stratified transition. The oil-water stability of separated flow will be examined with two types of stability analyses (following the Tailtel & Barnea approach for the gas-liquid case): the interfacial Kelvin-Helmothz (KH) analysis that indicates whether the interface is stable; and, the structural stability analysis that determines whether the steady-state solution is a stable structure with respect to the average water thickness, even if the interface is unstable owing to the KH analysis. The interfacial KH analysis includes two subtypes: the viscous KH analysis, which uses a full two-fluid model that takes into account the shear stresses; and, the inviscid KH theory in which the shear stress is neglected.

The dispersed flow region can be divided into the stratified-dispersed flow pattern and the fully-dispersed flow pattern. In the first one, the oil flows as a swarm of drops at the top of the pipe and the water remains at the bottom. The idea is to find a relationship between the stabilizing gravity force and the destabilizing forces due to surface tension and turbulent fluctuations in the top water layer. The fully-dispersed flow pattern transition will be addressed using the Hinze model, combined with the results for the inversion point presented by Arirachakaran. A drift flux model is also being considered for the prediction of these transitions. The way to proceed in this case is not yet well understood.

ICON ALLEY

Computer Upgrades

The reality of having four major research projects in the data acquisition stage has required additional computers. One of our Macintosh Centris 650s has been allocated to the Oil/Water project for data acquisition. We are covering the Horizontal Well and GRI projects with Macintosh IIci's and the Downflow project with a IIcx. Our first venture into the Macintosh Power PC world was a new 7100/66 machine for the staff engineer. Since Jerry Wilson is also our computer network supervisor, we felt he should get his feet wet and give the new platform a dry run. The Power PC has performed flawlessly and all new computers purchased from this point on will be Power PCs. Since these machines run all the old software in emulation mode, they have proved to be very reliable doing this, and we will be positioned to take advantage of increased speed as the new "Native" software upgrades become available.

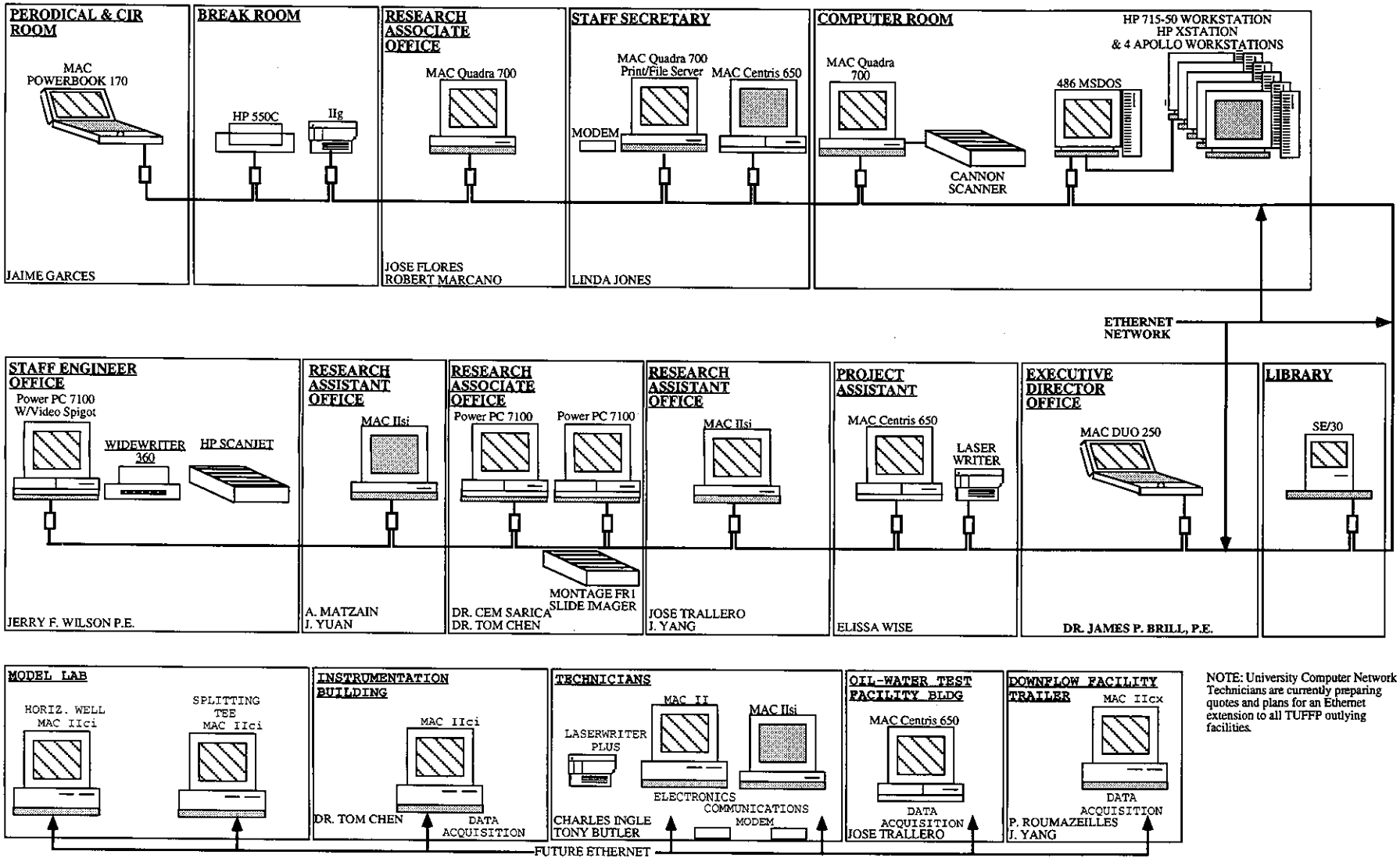
Having our new project assistant on board required the purchase of an additional computer. Two new Macintosh Power PCs were purchased for Drs. Sarica and Chen. Dr. Sarica's Centris 650 was transferred to Elissa Wise and Dr. Chen's Quadra 700 was placed in the computer room, replacing an old IIsi. Our old IIsi's are showing their age with monitor failures and very slow performance due to upgraded, power hungry software.

In an effort to improve the director's "on the road again" computing capabilities, a new Macintosh Duo 250 with docking stations has been purchased. Although this computer weighs considerably less than a previously used Powerbook 170, it is fast and versatile. The Duo 250 also has the built-in capability of running full size color monitors, which is an improvement over the Powerbook 170.

Another major effort is underway to strictly adhere to University computer policies by having only licensed copies of software in use. Having settled on specific software packages over the past two years, we now have sufficient licensed copies of all software to eliminate any conflict with University policy and copyright law.

A meeting was held last August with the University's associate provost for Computing and Information Resources, Reed Davis, to seek assistance in extending our Ethernet network to the TUFFP shops and outlying data acquisition buildings. We hope to complete this expansion before the end of 1994.

TUFFP COMPUTER NETWORK



NOTE: University Computer Network Technicians are currently preparing quotes and plans for an Ethernet extension to all TUFFP outlying facilities.

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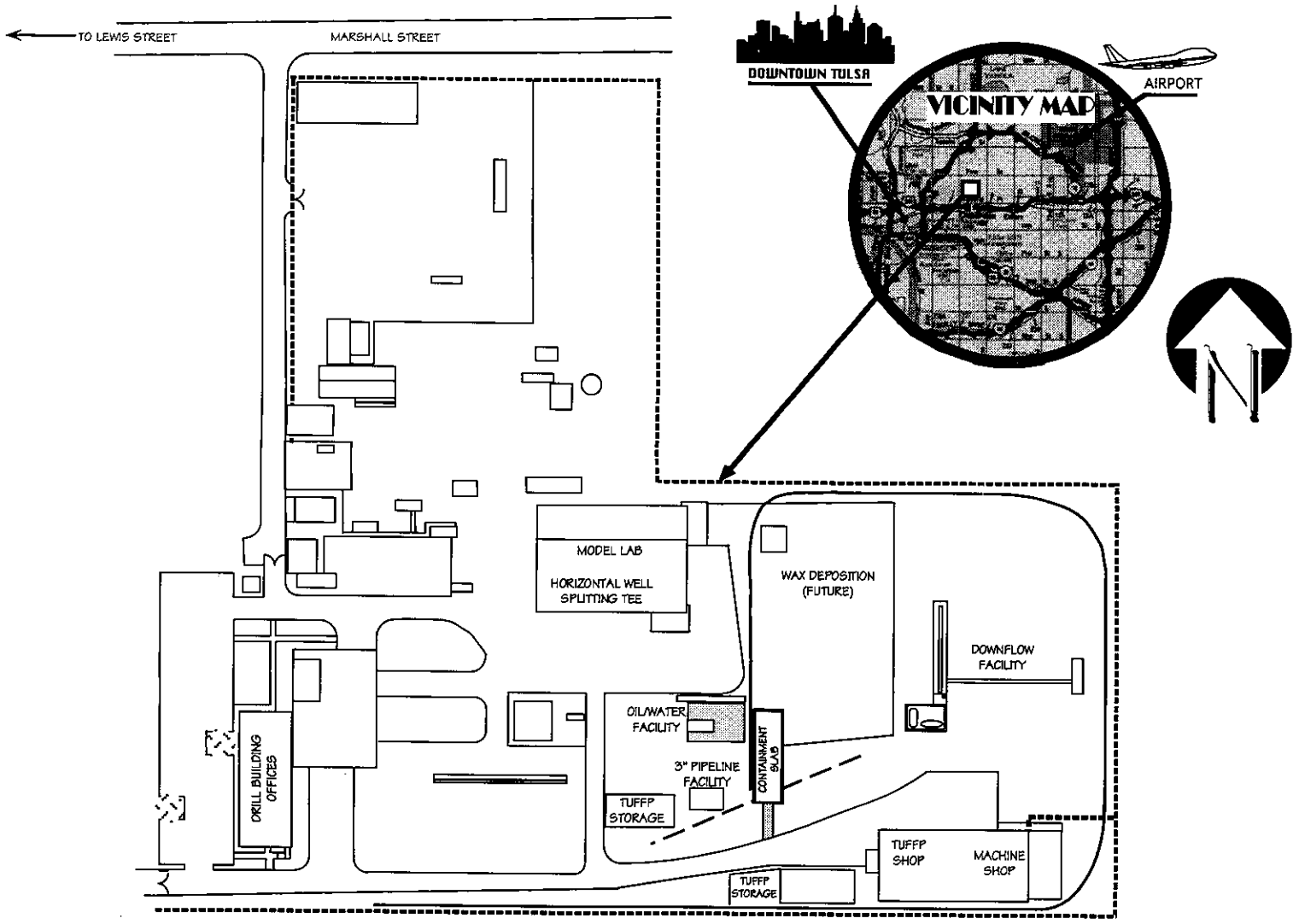
TUFFP COMPUTER LAYOUT DIAGRAM WINTER 1994



Department of Petroleum Engineering

FLUID FLOW PROJECTS SITE PLAN

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