TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS

NEWSLETTER

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Directory

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TUFFp Talk

Linda Jones Joins TUFFP

Linda joined the TUFFP staff on September 13, 1989. She assumed the position of Administrative Secretary that Rosa Jackson had vacated.

Linda has been with The University of Tulsa for approximately five years. She was the Petroleum Engineering Department secretary for almost two years and was then promoted to the position of Administrative Assistant for the new incoming Dean of the College of Engineering and Applied Sciences, Dr. Y. T. Shah. She held this position for over two years but chose to join the staff at TUFFP because she thrives on student contact.

Linda plans on being at The University of Tulsa, hopefully with TUFFP, for a long time. Her husband, David, is a Research Technician for the College of Engineering and Applied Sciences.

Advisory Board Meetings Scheduled

The next two Advisory Board meetings will be held May 8 - 9, 1990 and November 13 - 14, 1990. Both meetings will be held at the Sheraton Kensington Hotel in Tulsa, Oklahoma. Request for Information forms will be mailed to member companies approximately six weeks prior to each meeting to determine attendance. The forms will be accompanied by information pertaining to hotel reservations and accommodations to and from the airport.

The Advisory Board meetings will begin at 8:30 a.m. and will adjourn at 4:30 p.m. A pre-meeting cocktail party will be held at the Sheraton Kensington Hotel at 5:30 - 7:30 p.m. on Tuesday, May 8, 1990 and November 13, 1990. Tours of the TUFFP test facilities will also be held on these Tuesday afternoons from 3:00 - 4:30 p.m.

The above meeting dates were selected to accommodate those member companies that also attend Advisory Board meetings of other research consortiums at The University of Tulsa. The following is a summary of these meetings for May 1990.

Erosion/Corrosion	May 7, 1990
TUPREP	May 8, 1990
TUDRP	May 8, 1990
TUFFP	**May 9, 1990**
TUALP	May 10, 1990

TUFFP Advisory Board meeting brochures will be mailed to all members prior to the meetings. They will contain sufficient information to enable each attendee to 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 meetings but will not be mailed to members.

TUFFP Membership Continues to Remain Stable

Discussions continue to determine whether the National Iranian Oil Corporation (NIOC) and YPF from Argentina will indeed initiate membership in TUFFP for 1990

Other companies that are considering membership in TUFFP include the Oil and Natural Gas Commission of India, AGIP, Abu Dhabi Company for Onshore Operations, Schlumberger, and Petronas (Malaysia). Notification has been received that Texas Gas Transmission Corporation will terminate it's membership in TUFFP at the end of 1990.

TUFFP To Present Papers at Offshore Technology Meeting

Mr. Cem Sarica, a research assistant with TUFFP, will present a paper jointly authored by himself, Dr. O. Shoham and Dr. J. P. Brill at the 22nd Annual Offshore Technology Conference in Houston, Texas May 7 - 10, 1990. The title of the paper is "A New Approach for Finger Storage Slug Catcher Design". In addition, a paper at the same meeting will be presented by George Shoup that was co-authored by Dr. O. Shoham and is titled "Pipeline Design for Deepwater Gulf of Mexico Developments".

C Programming Seminar Held Weekly

Lorri Jefferson, the Computer Resources Manager, is conducting weekly seminars on the programming language C. The seminar is in response to the Research Assistants' desire to learn what has been labelled "the future programming language." The seminar will continue indefinitely.

TUFFP Networking Capabilities Expanded

TUFFP recently purchased USHARE, which connects the Appletalk network to the Apollo network. Each Macintosh now views the Apollo nodes as other hard disks on its desktop. This improved connectivity replaces the Kermit link, allowing virtual file transfers between any Mac and Apollo node in the TUFFP network.

TUFFP has also completed the extension of its Apollo network to include the PC's in the outside labs. Each PC used in data acqusition now houses an Apollo Ring Board, allowing it to act as a node in the Apollo network. The Ringboards allow each PC to view the Apollo nodes as directories on drive e: for example. Research Assistants previously transferred their data to the Apollos by using Kermit, PCI8 or floppies -- extremely slow and tedious processes. The Ring Board connectivity has greatly improved PC to Apollo comm-unication. Moreover, jobs on the Apollo can actually be ran from a remote PC.

Calendar for Two-phase Flow Technical Meetings Established

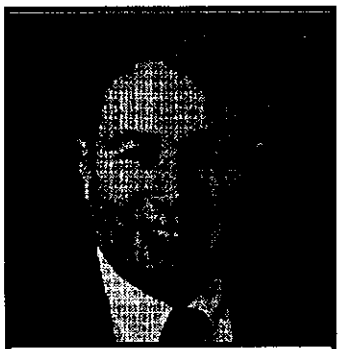
Several conferences are scheduled for 1990 which include technical sessions involving multiphase flow in pipes. A calendar of these events is given below.

May 9	**TUFFP ABM - Tulsa, Oklahoma**
May 10	TUALP ABM - Tulsa, Oklahoma
May 21 - 25	**TUFFP Short Course - Tulsa, Oklahoma**
August 19 - 24	9th International Heat Transfer Conference - Jerusalem, Israel
September 23 - 26	SPE Annual Fall Meeting - New Orleans, Louisiana
October 18 - 19	PSIG Meeting - Baltimore, Maryland
November 14	**TUFFP ABM - Tulsa, Oklahoma**
November 15	TUALP ABM - Tulsa, Oklahoma

TUFFP Graduate Seminars Continue

TIME	SPEAKER	TOPIC
March 2	**Kristian Brekke** Research Assistant	*Production:* Oil and Gas Three-Stroke Separation / Transportation Process
March 16 3:00 p.m.	**George Shoup** Distinguished Lecturer	*Two-Phase Flow:* Multiphase Flow Pumping
April 6 3:00 p.m.	**Mark T. Rubel** Distinguished Lecturer	*Two-Phase Flow:* Multiphase Flow Research Activities at Texaco
April 20 3:00 p.m.	**Dr. O. Shoham** Director of Research	*Two-Phase Flow:* Two-Phase Flow in Horizontal Wells

Reynolds Selected as New Petroleum Engineering Chairman


Dr. Al Reynolds

After conducting a nationwide search for a new Chairman of Petroleum Engineering at The University of Tulsa, Dr. Al Reynolds was selected for this position. He will assume his new duties on June 1, 1990 at which time Dr. E. T. Guerrero will retire. Dr. Reynolds is a world renowned expert on transient well test analysis and has been a driving force in the formation of the new research consortium "Tulsa University Petroleum Reservoir Exploitation Program". A superb teacher and researcher, Dr. Reynolds will continue to be a strong proponent of cooperative industry/ university research programs such as TUFFP.

Dr. Joe Middlebrooks Selected as Acting President of The University of Tulsa

The University of Tulsa was saddened with the death of Dr. Mike Davis, Acting President, in December 1989. Dr. Davis had served as Acting President since Dr. Twyman's death in May and during a period in which a national search for a new President was underway. Dr. Joe Middlebrooks, Provost at The University of Tulsa, will now serve as Acting President until the search process has been completed. We anticipate that a new President will be announced by late spring 1990.

TUFFP Financial Status Being Analyzed

Preparation of a financial summary to close the books for 1989 is currently underway. TUFFP entered 1989 with a deficit of $-50,797. Approximately $20,000 of this deficit was recovered during 1989. It is imperative that an attempt be made to eliminate the deficit during 1990. This will require a combination of reducing expenditures, obtaining new membership, and possibly deferring some expenditures until 1991. It is likely that an increase in membership fees will be necessary for 1991. This item will be discussed at the May Advisory Board meeting.

At present, 14 member companies have not yet paid 1990 membership fees. Prompt payment of membership fees from these companies will be appreciated.

Pam Brooks Redesigns TUFFP Library


Pam Brooks

Ms. Pam Brooks, a senior in Petroleum Engineering at The University of Tulsa, has been hired to reorganize the TUFFP library. This library is vitally important for Research Assistants conducting two-phase flow research for TUFFP. New books are continually being ordered and the library had reached a point where redesigning was necessary in order to facilitate efficient use of the information.

TUFFP Short Course Scheduled

Final details have now been completed for the TUFFP 1990 short course. An updated version of the standard TUFFP short course, "Two-Phase Flow in Pipes", will be held again in Tulsa, Oklahoma on May 21 - 25, 1990 at the Sheraton Kensington Hotel. The course will be taught jointly by Dr. Brill and Dr. Shoham.

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 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 structure that will be used for the short course. Brochures describing the course were mailed to members and other potential participants in early February.

TUFFP Member Companies:
Per Person $750
Group Discount - Per Person $650

Non-Member Companies:
Per Person $1,245
Group Discount - Per Person $995

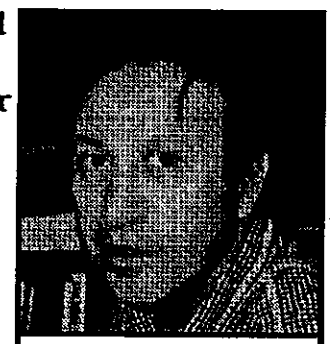
Some of the significant improvements that have been made in the short course include: a comprehensive mechanistic model for predicting two-phase flow in vertical wells; an improved method for predicting temperatures in flowing wells; a comprehensive mechanistic model for predicting two phase flow in horizontal pipes; and, new material on treating the flow behavior of oil-water emulsions as non-Newtonian fluids.

We urge member companies to enroll engineers as soon as possible. If insufficient enrollees are obtained by mid-April it will be necessary to cancel the course.

TUFFP Featured in Future Apollo Magazine

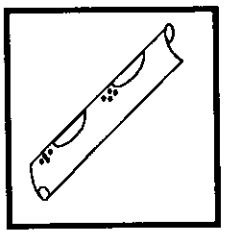
A spring issue of the Apollo Computer, Inc. magazine, The Cutting Edge, will feature the use of Apollo workstations in petroleum engineering research at The University of Tulsa. Featured in the article will be networks maintained by TUFFP and by the Petroleum Engineering Department. TUFFP has become recognized as a research program that maintains one of the most sophisticated computer networks in the world at an educational institution.

Dr. Taitel Consults for TUFFP


Dr. Yehuda Taitel

Dr. Yehuda Taitel again served as a consultant to TUFFP for a two-week period in February, 1990. During this time, he provided invaluable assistance to several TUFFP graduate students in modeling a variety of two-phase flow phenomena. Included were major modifications to models and the experimental design for a test facility to conduct research on two-phase flow in horizontal wells.

Research Projects



Slug Flow in Directional Wells

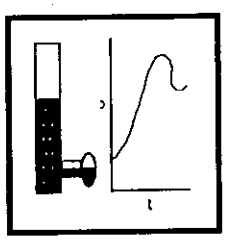
Ibere Alves

This project consists of a theoretical and experimental study of slug flow in upward inclined pipes such as directional wells. As the inclination angle varies from vertical to off-vertical, changes in two phase flow phenomena occur. Due to gravity, the gas phase tends to accumulate in the upper cross section of the pipe, causing the Taylor bubble rise velocity to change significantly. This peculiar behavior can have a substantial effect on the overall flow characteristics. Since the liquid holdup is strongly dependent on the Taylor bubble rise velocity, it also changes, causing the pressure gradient to be affected. An apriori knowledge of the characteristics of slug flow is essential for a proper design.

The design and construction of an experimental test facility has been completed. A new data acquisition system is being used that is based on a Macintosh computer. The hardware is manufactured by National Instruments and is installed in a MacII, with a resolution of 16 bits. The software, LabVIEW, is also marketed by National Instruments and uses a new programing concept. A graphical language which uses virtual instruments allows the user to create all the needed applications on the screen.

A special emphasis on the Taylor bubble rise velocity will be given in this study. This will include experimental measurements of the Taylor bubble rise velocity under both stagnant and flowing conditions. Analysis of the data will evaluate the accuracy of published correlations. An attempt will be made to developed a mechanistic model for predicting the Taylor bubble rise velocity.

The first set of data to be acquired will use infrared senors to measure Taylor bubble rise velocities for the entire range of inclination angles. Preliminary test runs for vertical and sharply inclined flow have been completed. Currently, more data are being acquired, increasing the inclination angle range and the number of runs, to have as broad a data bank as possible. In the second phase of the project, data pertaining to slug characteristics will be acquired and a slug flow model for directional wells will be developed.



Wellbore Phase Separation Phenomena in Pressure Buildup Tests

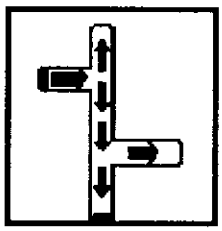
Metin Gokdemir

The objective of this study is to develop a model for predicting the effects of wellbore phase redistribution on bottomhole pressure buildup behavior. The phenomenon of wellbore phase redistribution occurs in a well operating under two-phase flow conditions. Surface shut-in of the wells for pressure build up tests can cause phase separation in the wellbores, which produces an increase in bottomhole pressure. This

increase manifests itself as a hump in pressure build-up curves, making their interpretation more difficult.

The long term objectives of TUFFP for this project will be carried out in two phases. The first phase includes the development of a model for the wellbore hydrodynamic behavior only. In the second phase the wellbore model will be extended and coupled with the reservoir flow behavior. This phase will also include experimental work for verification and modification of the developed model.

Since the last Advisory Board meeting the drift flux model has been used to formulate the phenomenon. The new drift flux model is currently being implemented and preliminary results will be presented at the May 1990 Advisory Board meeting.



Slug Flow Splitting Phenomena in Side-Arm & Impacting Tees

S. Arirachakaran

The primary objective of this study is to investigate slug flow splitting at a regular horizontal side-arm tee. A physically-based model which describes preferential liquid movement through this pipe tee configuration will be developed, compared with other applicable published models, and verified with the currently-acquired and other published experimental data.

The modified circuit for the existing 2-in air-water capacitance sensor design was finished and tested on-line. Unfortunately, it was neither stable nor sufficiently reliable for consistent readings of holdup values. A decision was made to pursue the new design of both the circuit and the physical assembly developed by Tony Butler to correct all the shortcomings previously addressed from the old design. A prototype sensor was developed and statically calibrated successfully. The output signals are stable and consistent. Steps are now being taken to assemble three of these newly-designed sensors for on-line testing. A few piping changes must be made in the test facility to incorporate these sensors in the flow loop, since they are not portable. Thus, the sections of the flow loop in which these sensors are to be installed must be replaced.

Efforts are being made to complete the Fortran coding of the proposed slug flow splitting model, which consists of two algorithms. The first is the split of the slug body, which is modeled after the "Breaking-of-a-Dam" concept. The second routine is the split of the gas pocket or film region. This can be achieved by applying the modified Shoham et al. stratified splitting model from a previous study at TUFFP. Any necessary modifications of these algorithms will be made as necessary after completion of the data acquisition.

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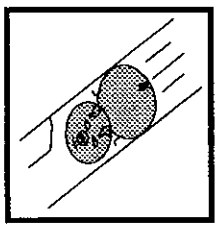


Modeling Pigging Dynamics in Two-Phase Pipelines

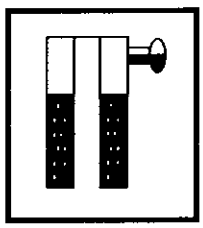
Kazu Minami

Knowledge of the flowing characteristics of a wet-gas pipeline under pigging operation is crucial for proper design and operation of both the pipeline and the downstream liquid handling facilities. In this study, the complex transient phenomena that occur during a two-phase pipeline pigging operation will be investigated theoretically and experimentally.

The pigging model will consist of separate models for each flowing section encountered during a pigging operation, namely, undisturbed two-phase flow section; liquid slug section; gas flow section; and, redeveloping two-phase flow section. For the last two sections, the simplified transient model developed by Taitel et al has been found to be suitable, and will be used with certain modifications. A model for predicting the slug characteristics in the slug section ahead of the pig has already been completed.

The experimental part of this project will be conducted using the 1400 ft long, 3 in. diameter horizontal pipeline, using a kerosene-air mixture. The test loop is under modification to install necessary instrumentation and devices. Eight newly designed capacitance sensors were built during the past fall and are ready to be mounted on the pipeline. A new remotely operated pig launcher, designed by Burt Vernooy & Associates Inc., is currently under construction at TUFFP. The fast PC microcomputer based data acquisition system, previously utilized in the project "Two-Phase Slug Flow in Hilly Terrain Pipelines," has been moved to the metering building. Rewiring of the instruments is gradually being done as weather permits.

The data gathering phase will be divided into two stages. Transient data without pigs will first be acquired and test runs with pigs will then be conducted. The first set of data will permit the evaluation of the various transient models, while the second will enable the overall performance analysis of the pigging model.



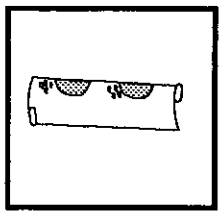
Mechanistic Model Determination of Bottom Hole Pressure in Pumping Wells

D. Papadimitriou

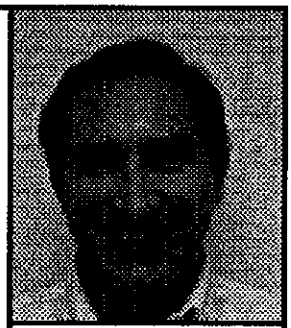
The objective of this study is to develop a model for the prediction of bottomhole pressures during steady state operation in pumping wells. The model takes into consideration recent developments in two-phase flow, such as flow through an annulus configuration, and is based on the concept of zero net liquid flow.

Since the last Advisory Board meeting, models for slug and bubble flow under zero net liquid flow have been developed. The present model consists of two parts. First, the existing flow pattern at any given point is predicted. Next, the corresponding pressure gradient is determined based on the models for slug and bubble flow. Finally, the bottomhole pressure is calculated by integrating the pressure gradient distribution along the annulus. These models have been combined into a computer simulator. Efforts are now being

focused on testing the model against field data. Also, a sensitivity analysis will be carried out to investigate the important parameters affecting annulus bottomhole pressure. The final report of this study is scheduled for May 1990.



Evaluation of Slug Models for Horizontal Pipes



Carlos Daza

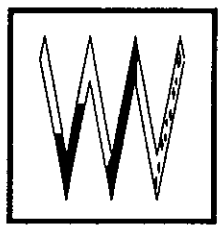
The objective of this project is to formulate a new model for horizontal slug flow that is applicable for both small and large diameter pipe.

A horizontal slug flow data base has been established with the following data:

- The TUFFP 3-in. diameter air-kerosene data collected by Kouba. A total of 53 runs are available with operational and slug flow characteristics data.
- The Creare data for slug flow in a 6.75-in. diameter pipe. These include 14 data points for high and low gas density.
- The SINTEF data from an 8-in. diameter pipe. Eight data points from a nitrogen-diesel system are available.
- The BHRA air-water data for slug flow in large diameter pipes. These data include two sets of experiments: a) 21 tests from an 8-in. diameter pipe, and b) 29 tests from a 16-in. diameter pipe.
- The Prudhoe Bay data for gas-oil slug flow in large diameter pipes. These data include eight points for 16 and 24-in. diameter pipes.

A review of the models for slug flow in horizontal pipes has been completed. Four models are considered in this study: the Dukler and Hubbard model (1975), the Creare model (1986), a simplified model, and the Brill et al. correlation (Prudhoe Bay model). Other slug flow relationships have also been considered. Fortran codes for each of the reviewed models have also been developed for the purpose of evaluation against the data base.

After running all the considered models using the data base, a new slug flow model has been developed, resulting in remarkable improvements of the pressure drop predictions in both small and large diameter pipelines. Efforts are being made currently to formulate an improved correlation for the prediction of slug frequency.



Two-Phase Flow in Low Velocity Hilly Terrain Pipelines

Cem Sarica

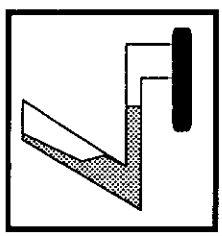
The primary objective of this study is to investigate two-phase flow in low velocity hilly terrain pipelines. This includes development of a model to predict the complex nature of the flow in such systems. The model will be the basis for a computer simulator suitable for design purposes. Finally, since the model is based on physical principles, it can be used to compare with available, more general, elaborate numerical schemes.

Hilly terrain pipelines with low flow rates of gas and liquid are often encountered in nearly depleted fields and fields in their early development stage. The flow in these pipelines is gravity dominated. Liquid tends to accumulate in the lower

sections or valleys, with gas above it. The flow behavior of such low velocity pipelines can be complex, even for constant input flow rates. Possible unsteady conditions may develop in the upward inclined sections (risers) due to accumulation of compressible gas upstream.

Severe slugging in pipeline-riser systems can be considered as a special case of low velocity flow in pipelines. Therefore, in the first stage of this project, an improved model has been developed to simulate transient flow behavior in pipeline-riser systems. The model and other existing models are being tested against a broad range of experimental data. The results show that the present model more accurately predicts the system variables such as pipeline pressure transients, liquid accumulation, and cycle time.

A simplified low velocity flow model is currently being developed for hilly terrain pipelines. Simulation studies are expected to be completed by May 1990.

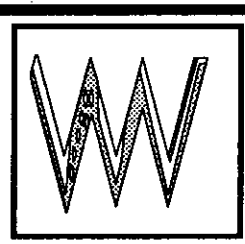


Elimination of Severe Slugging in a Pipeline-Riser Sytem

Finn Erik Jansen

Phase II of this project, Elimination of Severe Slugging in Pipeline-Riser Systems, is now approaching its completion. The experimental part has been completed and data for four different elimination conditions have been acquired. The elimination methods studied are: choking, gas lift, back pressure increase and a combination of choking and gas lift. All methods were found to eliminate severe slugging. However, back pressure increase causes too high of a pressure increase in the system to be an efficient method. Choking was found to be the single method which most efficiently eliminated severe slugging. Unfortunately, choking will also cause a pressure increase in the system. Gas lift was found to require large amounts of injected gas before eliminating the severe slugging, but would reduce the system pressure. The most efficient way of eliminating severe slugging was found to be a combination of low choking together with relatively small amounts of injected gas. This method seems to combine the best features of both methods and reduce the severity of the slugging, together with reducing the average system pressure.

Two models have been developed. One model is based on the stability analysis by Dr. Taitel (1986) and the second model is an updated version of the quasi-equilibrium model presented by Vierkandt (1988). Good results have been achieved with the stability model, while the quasi-equilibrium model has not yet been completed. A final report is anticipated in April, 1990.



Comprehensive Mechanistic Model for Two-Phase Flow in Pipelines

J. Xiao

The objective of this project is to develop a comprehensive mechanistic model for two-phase flow in horizontal and near horizontal pipelines. The model will be able to predict the flow pattern and then other flow characteristics such as liquid holdup

and pressure drop for each of the flow patterns. A pipeline data bank will be generated, against which the model will be evaluated.

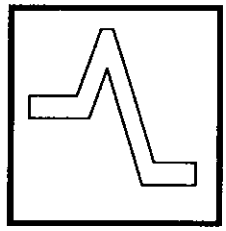
The following have been accomplished since the November 1989 Advisory Board meeting:

1. The TUFFP pipeline data bank has been expanded by adding data from the following sources:
   - Mcleod et al.: Data from a field test in a 6.065-in. pipeline.
   - Eaton et al.: Data from experiments conducted under field conditions in 2-in. and 4-in. horizontal pipes. Water, distillate or crude oil were used as the liquid phase, and natural gas was used as the gas phase.
   - Beggs & Brill: Data for air-water two-phase flow from 1-in. and 1.5-in. pipes with inclination angles of -10° - +10°.
   - Minami & Brill: Liquid holdup data from 3.068-in. horizontal pipes with kerosene and water as the liquid phase and air as the gas phase.
   - Payne and Palmer: Water and natural gas two-phase flow data in a 2.067-in. hilly terrain configuration.

2. Correlations for interfacial friction factor for stratified flow have been evaluated. It has been found that none of the available correlations gives very satisfactory results.

3. The Daza slug flow model has been incorporated into the comprehensive model and is ready for further assessment.

Future work includes an overall evaluation of the comprehensive mechanistic model against the whole data bank and an evaluation of each of the flow pattern models. More results will be presented at the May 1990 Advisory Board meeting.



Two-Phase Slug Flow in Hilly Terrain Pipelines

Gouhua Zheng

This project examines, experimentally and theoretically, the effect of pipe inclination angle on slug flow characteristics in shallow inclined pipelines.

In the experimental part, more than 100 tests were conducted in the 3 in. TUFFP pipeline flow loop, covering a wide range of flow rates within inclination angles from 1° to +5° from the horizontal. A microcomputer based data acquisition and control system was utilized for collecting a large amount of data from 9 ring capacitance sensors, 8 pressure transducers and other instruments. Part of the data has already been analyzed in terms of individual slug characteristics. These include slug length, slug translational velocity, and liquid holdup in the slug and film regions. The rest of the data will also be analyzed in a similar manner.

In the theoretical analysis, a drift velocity model for the inclined slug flow has been formulated. The model applies the Benjamin (1968) potential flow theory and extends Kouba's (1986) analysis for horizontal slug flow to inclined flow. Independent models for slug frequency and for liquid holdup in the slug region are also being developed. These two parameters are necessary to close the model for inclined slug flow. The new model will be presented in the May 1990 Advisory Board Meeting.

Two Phase Flow in Horizontal Wells

Masaru Ihara

The objective of this project is to investigate theoretically and experimentally the flow behavior in horizontal wells.

The theoretical part includes the development of a model and a computer simulator for the prediction of steady state two-phase flow in horizontal wells and its interaction with the reservoir.

The experimental part includes the design and construction of a small scale experimental test facility and acquiring the pertinent data for testing the theoretical model. The liner slots will be simulated by several small diameter pipes distributed along the horizontal liner. Inlet gas and liquid flow rate in each of the small diameter pipes will be controlled and measured. Pressure drop and holdup distribution along the horizontal well pipe will be measured by pressure transducers and capacitance sensors.

Efforts are now being focused on completing the literature search on flow behavior in a horizontal well configuration.

1990 TUFFP Members

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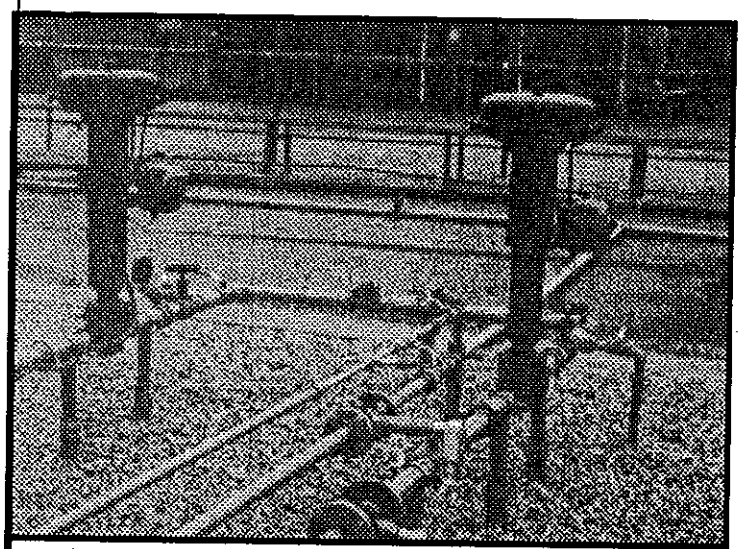
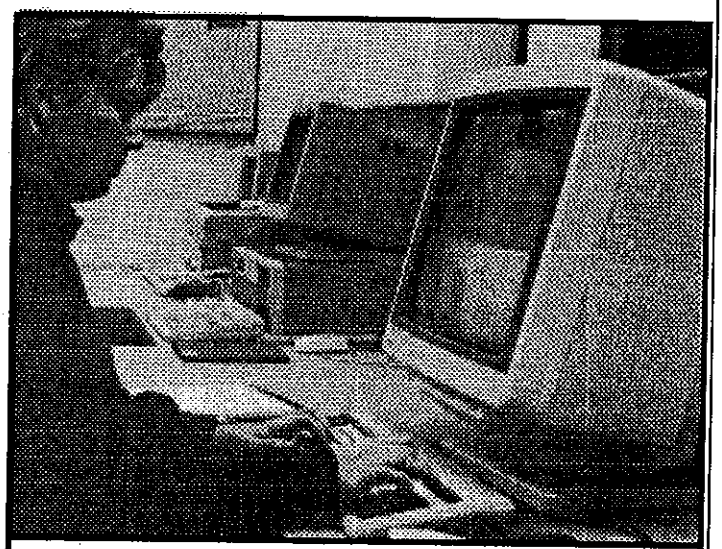
Texas Gas Transmission Corp.
Unocal Corp.



Slug Flow in Directional Wells Test Facility



TUFFP Computer Room

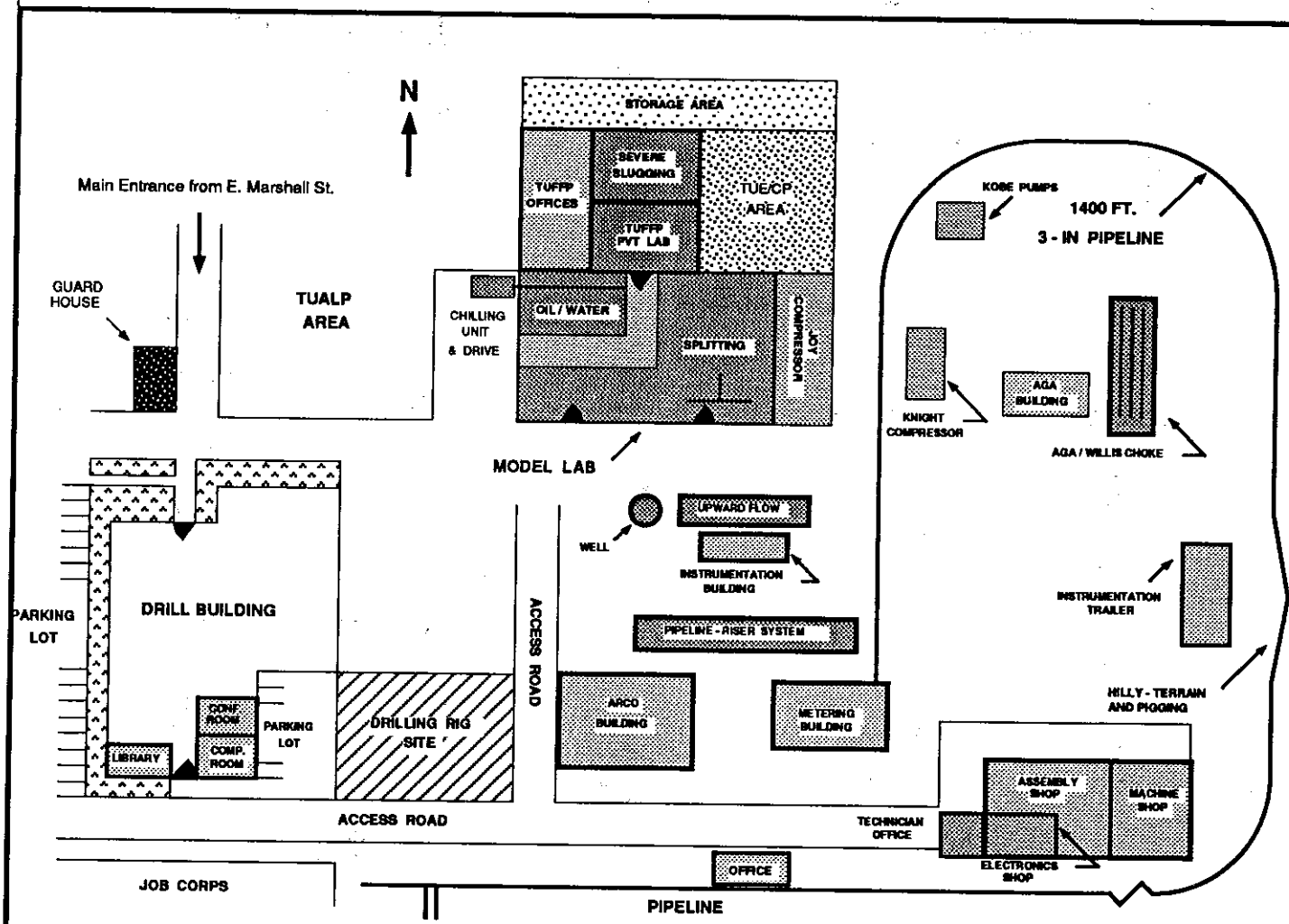
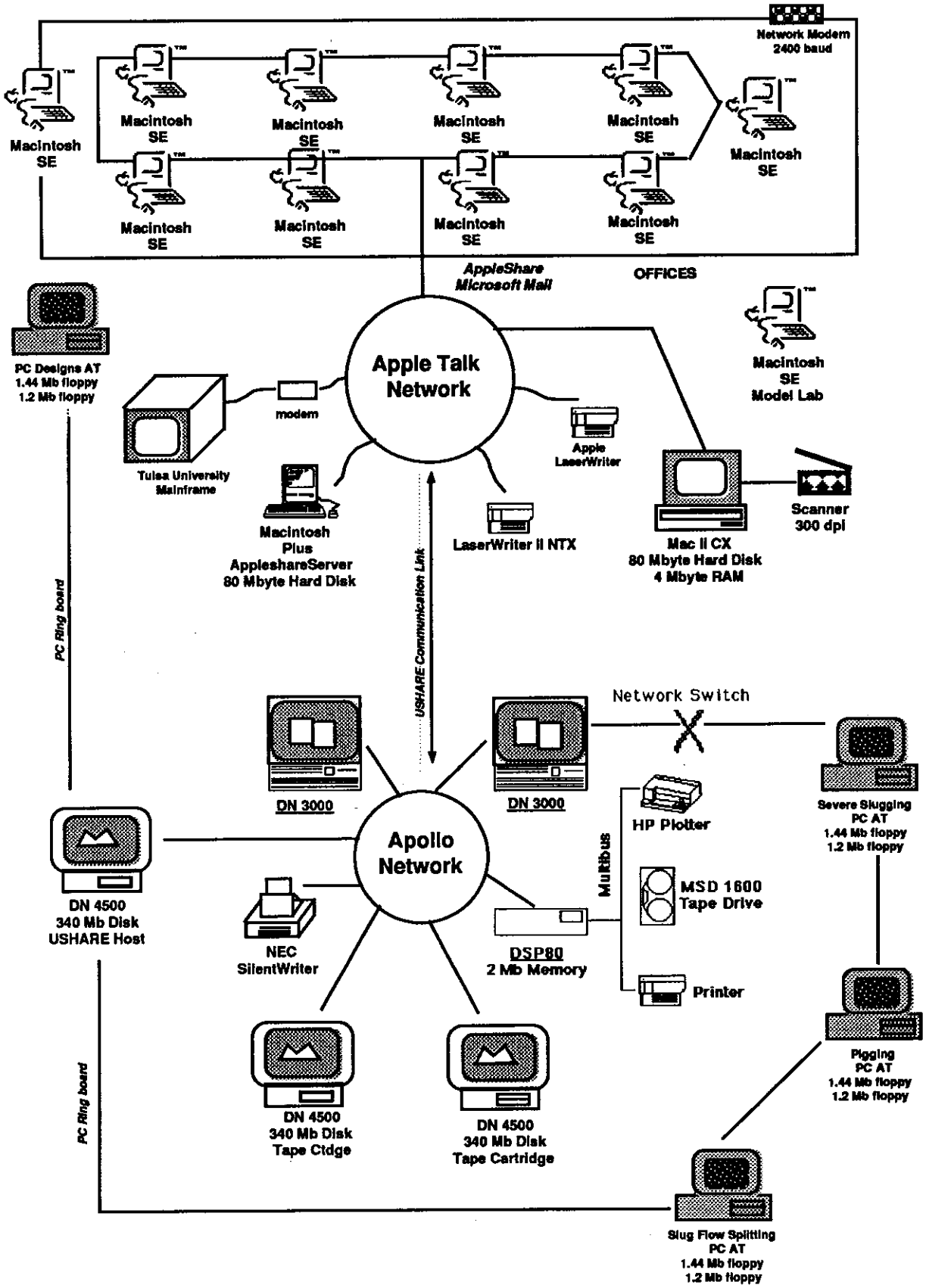


Illustration of TUFFP Test Facilities



TUFFP Computer Network