TUFFP

TULSA UNIVERSITY FLUID FLOW PROJECTS NEWSLETTER

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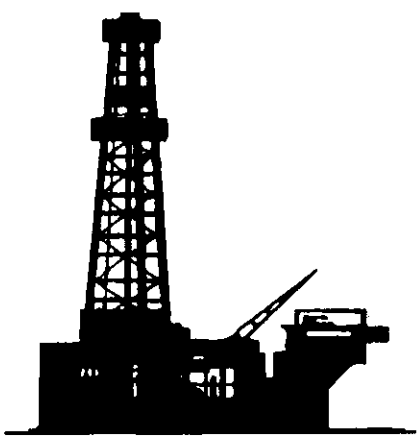
DIRECTORY



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TUFFp Talk

Five TUFFP Graduate Students Complete Research Projects

In an unprecedented flurry of activity over an eight-day period in mid-August, three Ph.D. candidates and one M.S. candidate in Petroleum Engineering all successfully defended their completed research. This included Ibere Alves, Kazu Minami, and Guohua Zheng for the Ph.D. degree and Metin Gokdemir for the M.S. degree. In addition, Masaru Ihara successfully defended his M.S. thesis in mid-July.

Each of these students deserves our most sincere congratulations. Most of the projects have been underway for several years, and several will be continued in the future with other students.

Reports on each of these projects are in the final editing stage, after which they will be printed and distributed to TUFFP members. Final abstracts of the reports appear later in this newsletter.

Ibere Alves and Kazu Minami will be returning to Petrobras after finishing all final details pertaining to their research. Dr. Minami will be rejoining CENPES, Petrobras' research center, and Dr. Alves will be rejoining the Production Department. Dr. Zheng has accepted a position in the Multiphase Simulation Group at Texaco's Bellaire facility in Houston. Masaru Ihara has returned to the Technology Research Center for JNOC in Tokyo. Finally, Metin Gokdemir will continue his work towards a Ph.D. degree on a part-time basis, having accepted a position with the Amoco Production Research Center in Tulsa.

Increase in TUFFP Membership Anticipated

At this time it appears likely that TUFFP will have four new members in 1992 — AGIP, Elf Aquitaine, Institut Francais du Petrole, and Instituto Colombiano del Petroleo. (Two may join in 1991.) Since no cancellations have been received for 1992, we anticipate that we will enter 1992 with 33 member companies. A list of 1991 TUFFP members appears on page 9.

TU Fills Key Administrator Positions

We are pleased to announce that Dr. George Gilpin, formerly of the University of Miami, is now The University of Tulsa's Provost and Academic Vice President. In addition, Mr. Reed Davis, formerly of the University of Arizona, was selected to be The University of Tulsa's first Associate Provost for Computing. The search for a new Dean for the College of Engineering and Applied Sciences continues. During the interim period, Dr. Steve Bellovich is serving ably as Acting Dean.

Advisory Board Meetings Scheduled

The next two Advisory Board meetings will be held November 12 – 13, 1991, and tentatively, May 12 – 13, 1992.

The November meeting will be held at the Doubletree Hotel at Warren Place in Tulsa, and the May meeting will be held either at the same hotel or at the Sheraton Kensington 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 November Advisory Board meeting will begin at 8:30 a.m. on Wednesday, November 13, 1991, 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 5:30 – 7:30 p.m. on Tuesday, November 12, 1991. A tour of TUFFP test facilities also will be held on Tuesday afternoon from 3:00 – 4:30 p.m.

The May 1992 meeting date was selected to immediately follow the Offshore Technology Conference in Houston, May 4 – 7, 1992, and to precede the TUFFP short course on "Two-Phase Flow in Pipes" that has been scheduled for May 18 – 22, 1992 at the Sheraton Kensington Hotel in Tulsa.

The above 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 these meetings for November 1991:

Erosion/Corrosion	November 11, 1991
TUPREP	November 12, 1991
TUDRP	November 12, 1991
TUFFP	**November 13, 1991**
TUALP	November 14, 1991
TUWRP	November 19, 1991

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 Recruits New Research Assistants

Peter Ashton from Birmingham, England has joined TUFFP to pursue an M.S. degree in Petroleum Engineering. Peter just received his bachelor's degree in Petroleum Engineering from the Colorado School of Mines.

V. Raju Penmatcha from India has also joined TUFFP to pursue an M.S. degree in Petroleum Engineering. Raju received his B.S. degree in Chemical Engineering from the Andhra University in India this past May.

Rao Deverakonda is also from India and will be pursuing an M.S. degree in Petroleum Engineering with TUFFP. Rao received his B.S. degree in Chemical Engineering from the Andhra University in 1982. In 1985 he received a Master of Technology degree in Chemical Engineering from the India Institute of Technology in Bombay. Rao has five years of research and practical training experience with the Oil and Natural Gas Commission in India.

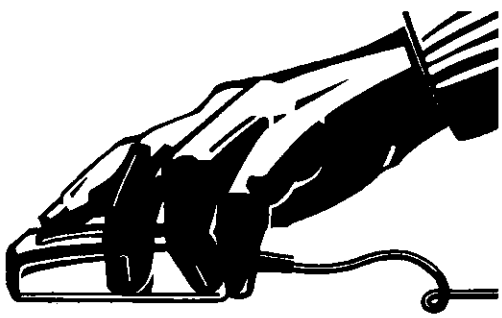
In addition to these three new students, Rafel Paz, the top Petroleum Engineering undergraduate student at The University of Tulsa last year, plans to join TUFFP in January to begin pursuit of his M.S. degree.

Discussions are underway with Jose Luis Trallero of Intevep in Venezuela to begin a Ph.D. degree program in late 1992. Mr. Trallero attended short courses taught by Dr. Brill and Dr. Shoham in Venezuela last year and is involved actively in multiphase flow research for Intevep.

BHRG Conference In France a Big Success

An exciting array of technical papers on the subject of multiphase flow in pipes was presented at the BHRG 5th International Conference on Multiphase Production in Cannes, France on June 19 – 21, 1991. Approximately 150 people from virtually every continent gathered together to listen to 35 technical papers on a variety of subjects ranging from gas liquid separator behavior to complex mechanistic models.

Based on the successful conference in 1991, BHRG has made a tentative decision to have a 6th International Conference on Multiphase Production in Cannes, France in June 1993.



Software/Data Distribution Program Plans Underway

Plans to initiate an improved program for distribution of data and computer programs to TUFFP member companies are proceeding slowly. An initial phase to determine the type of media for the distributions will be pursued this fall as part of the annual questionnaire. The distribution media also could be affected by a possible upgrading of TUFFP computer equipment. Depending upon the results of the survey, it also may be necessary to order additional equipment to fill all members' needs.

TUFFP Financial Status — A-OK!

Minor changes have been made in planned expenditures over the summer, and a revised budget confirms that the current financial condition of TUFFP is excellent. The increase in membership fees for 1991, together with an increase in the number of members, has permitted TUFFP to eliminate its deficit position completely. Membership fees for 1992 will again be $20,000. At the present time, four member companies have not yet paid their membership fees for 1991. However, all have been contacted and payment is anticipated in the near future.

TUFFP Helps INTEVEP With Capacitance Sensors

INTEVEP is in the process of constructing a multiphase flow test facility in Venezuela that will incorporate holdup measurements. One of its engineers, Jose Luis Trallero, visited TUFFP for one week this summer to observe the construction and operation of our capacitance sensors. Mr. Trallero, who hopes to return to TUFFP as a Ph.D. student in 1992, spent a week with TUFFP electronics technician, Tony Butler, working on this project. They discussed the theory and operation of the capacitance sensor, built prototypes, and practiced calibration and trouble-shooting. INTEVEP then purchased the necessary electronic components to build three capacitance sensors for its test facility.

Although, the TUFFP capacitance sensor is operating reliably with kerosene-air mixtures, it is not yet satisfactory for dynamic holdup measurements for facilities that currently use air-water mixtures. The ratio-arm bridge presently used may not be feasible for conductive fluids. A new approach is being investigated using a constant voltage conversion. This type of capacitance measurement offers the advantage of being independent of excitation frequency. Also, it does not require an external carrier demodulator, reducing expense and increasing immunity to noise. Member companies will be kept informed of future developments of the capacitance sensors.

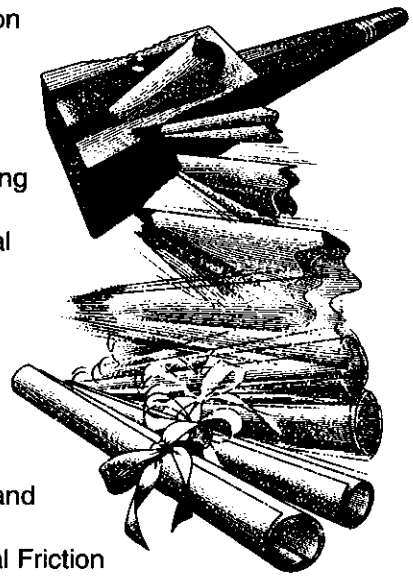
OCAST Funds Second Research Project at TUFFP

Dr. Ovadia Shoham was awarded a $124,704 research grant by the Oklahoma Center for the Advancement of Science and Technology (OCAST) for a three-year period beginning September 1, 1991. The funds will be used to continue TUFFP research on two-phase flow splitting at a tee junction, but with an inclined side arm. During the three-year period, TUFFP is scheduled to match OCAST funding with $142,267, most of which represents facility rental charges. TUFFP will, however, provide technician and supervisory costs for the project. Final research reports will be distributed to all TUFFP members.

1991 TUFFP Questionnaire

The 1991 TUFFP Questionnaire was distributed to the official Advisory Board representative for each member company with this newsletter. Members were asked to express their relative interests on both existing and possible future research projects. Results will be tabulated and summarized in the November Advisory Board meeting brochure. Also included in the questionnaire was a survey of the preferences from each member company on the media for distributing computer programs and data.

TUFFP Presents Several Papers at Technical Meetings



Seven papers based on TUFFP research activities have or will be presented at five different technical meetings during 1991. The following three papers will be presented at the SPE Annual Technical Conference and Exhibition in Dallas, Texas on October 6 – 9, 1991.

- "Two-Phase Flow in Low Velocity Hilly Terrain Pipelines," by C. Sarica, O. Shoham and J. P. Brill, SPE 22762
- "Evaluation of Interfacial Friction Factor Correlations for Gas/Liquid Stratified Flow," by J. J. Xiao and O. Shoham, SPE 22765
- "Intelligent Utilization of a Unified Flow Pattern Prediction Model in Production System Optimization," by S. Arirachakaran, D. A. Papadimitriou, L. L. Jefferson, J. P. Brill and O. Shoham, SPE 22869.

In addition, a paper was presented at the SPE Petroleum Computer Conference in Dallas, Texas on June 17 – 20, 1991.

- "Complete Multi-Platform Networking Integration in a Petroleum Research Environment," by L. L. Jefferson, S. Arirachakaran and J. P. Brill, SPE 22299, also published in SPE Computer Applications, July/August, 1991.

The following paper was presented at the BHRG 5th International Conference on Multiphase Production in Cannes, France on June 19 – 21, 1991.

- "Simulation of Multiphase Flow Behavior Causing Catastrophic Accident at South Pass Block 60B-Platform, Offshore Louisiana," by J. P. Brill and C. Sarica.

Much of the TUFFP research activity is of significant interest to companies that operate in the gas transmission area. Consequently, TUFFP periodically participates in the Pipeline Simulation Interest Group (PSIG). A paper is scheduled to be presented at the 23rd Annual PSIG meeting in Minneapolis, Minnesota on October 24 – 25, 1991.

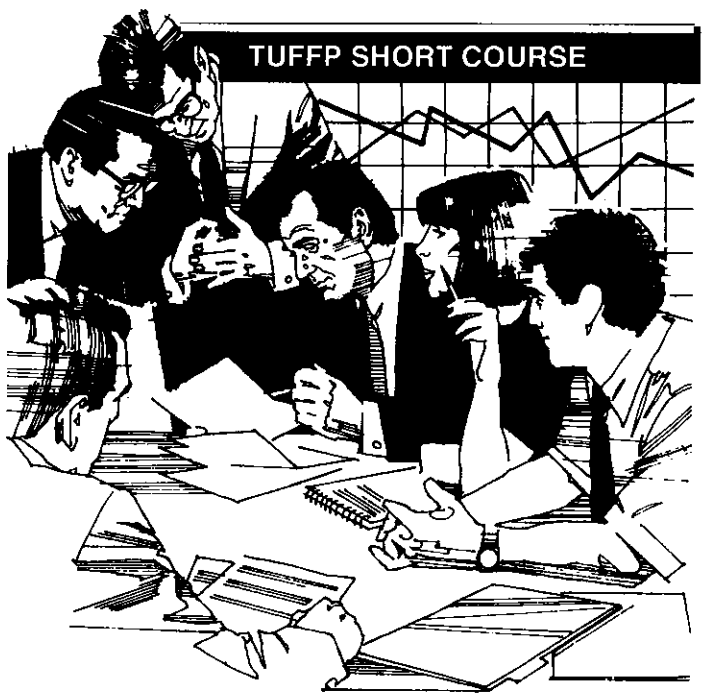
- "An Application of Modern Two-Phase Flow Splitting Models in Hydrocarbon Network Analysis," by J. P. Brill and S. Arirachakaran.

Finally, a paper is also scheduled to be delivered at the AIChE Annual meeting in Los Angeles, California on November 17 - 21, 1991.

- "A New Modeling Approach to Two-Phase Slug Flow Splitting at a Regular Horizontal Side-Arm Tee," by S. Arirachakaran, O. Shoham and J. P. Brill

Yehuda Taitel Consults for TUFFP Again

Dr. Yehuda Taitel returned to TUFFP for a period of six weeks this summer as a consultant. His trip this year was especially beneficial to TUFFP because of the large number of students who were in the final stages of their research. We are grateful that he has continued to be available and acknowledge his unique creativity in stimulating student thoughts and initiating many of the major breakthroughs that we have experienced in the past several years. We anticipate his return during the summer of 1992.



TUFFP Short Course Is a Big Success Again

A very successful short course on "Two-Phase Flow in Pipes" was held May 20 – 24, 1991 in Tulsa, Oklahoma. The course was attended by 28 engineers, including 23 from 11 TUFFP member companies, 4 from non-member companies and one guest from Texas A&M University. Income from the course was sufficient to pay all expenses incurred.

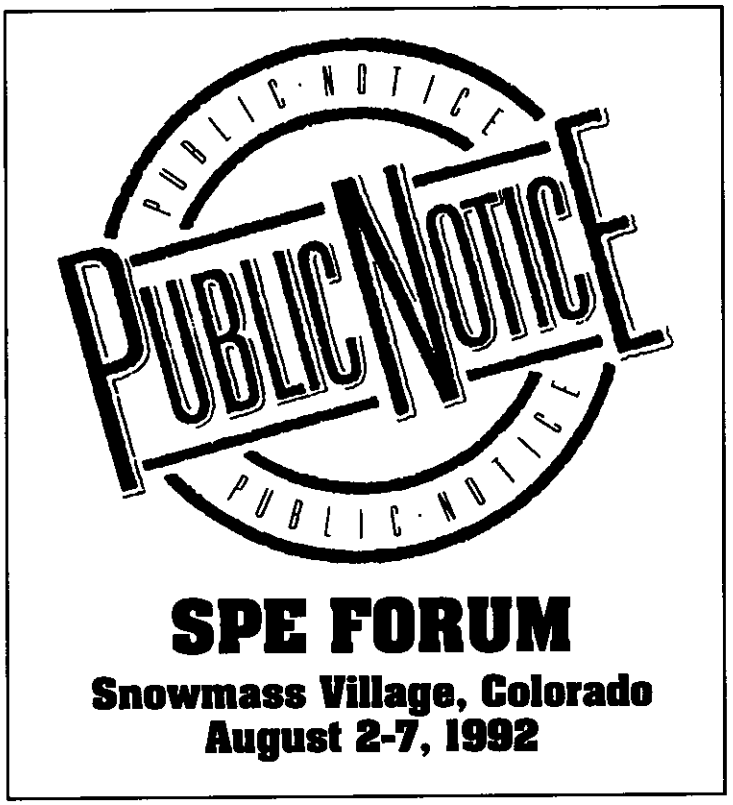
On the basis of the successful 1991 course, we have scheduled the course again in Tulsa for May 18 – 22, 1992 at the Sheraton Kensington Hotel. More information pertaining to the short course will be presented at the November 1991 Advisory Board meeting, and brochures will be available to member and non-member companies at that time. A decision has been made to increase the enrollment costs for all categories of attendance by $200 per person. Thus, TUFFP members would now pay $950 for one enrollee and $850 for the group rate.

Summer Students Help Out at TUFFP

Four students were hired full-time to assist with TUFFP activities during the summer of 1991. Two of these, Bayram Kara and Aziz Abdul, provided invaluable assistance to Dr. Zheng, Dr. Alves and Dr. Minami during the final stages of their research projects. In addition, Haris Basran and Zaheed Haque, undergraduate students in Petroleum Engineering and Electrical Engineering, respectively, were extremely helpful during a major maintenance program of TUFFP test facilities. Finally, Talal Al-Subhi helped on a part-time basis with organizing the TUFFP library.

SPE Forum on Multiphase Flow Scheduled

Members should mark their calendars for the first SPE Forum ever held on the subject of multiphase flow in pipes. The Forum Series has been an extremely successful approach for SPE to gather experts in specific areas for a week of intense technical exchanges. A Forum on multiphase flow is scheduled for Snowmass Village, Colorado on August 2 – 7, 1992.



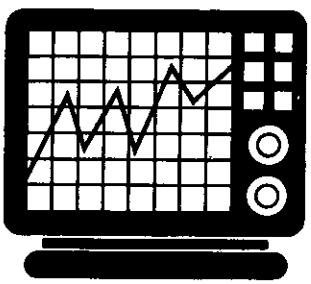
Calendar for Two-Phase Flow Technical Meetings

Several conferences that include technical sessions involving multiphase flow in pipes are scheduled for 1991 and 1992. A calendar for these events is given below.

1	Sept. 3 – 6	SPE Offshore Europe — Aberdeen, Scotland
	Sept. 21 – 27	International Conference on Multiphase Flow — Tsukuba, Japan
9	Oct. 6 – 9	SPE Annual Technical Conference and Exhibition — Dallas, Texas
	Oct. 24 – 25	PSIG Meeting — Minneapolis, Minnesota
9	**Nov. 13**	**TUFFP ABM — Tulsa, Oklahoma**
1	**Nov. 14**	**TUALP ABM — Tulsa, Oklahoma**
	Nov. 17 – 21	AIChE Annual Meeting — Los Angeles
	Mar 8 – 11	SPE Latin American Petroleum Engineering Conference — Caracas, Venezuela
1	Mar 24 – 27	SPE International Meeting on Petroleum Engineering — Beijing, China
9	May 4 – 7	Offshore Technology Conference — Houston, Texas
	May 13	**TUFFP ABM — Tulsa, Oklahoma**
9	**May 14**	**TUALP ABM — Tulsa, Oklahoma**
	May 18 – 22	**TUFFP Short Course — Tulsa, Oklahoma**
2	Aug. 2 – 7	SPE Forum on Multiphase Flow — Snowmass Village, Colorado

Bits & BYTES

TUFFP Evaluating Alternatives For HP/Apollo Work Stations



TUFFP is in the process of evaluating possible alternatives for its HP/Apollo work station network. The growing needs of TUFFP students, the fast-developing technology in the work station market, and the obsolescence of the current system necessitate this evaluation. The two alternatives under consideration are: leasing a new HP 730 work station; or, upgrading the 4500s to 5500s. Currently, TUFFP has three 4500 and two 3000 Apollo work stations running under the Domain operating system. The speeds of these work stations are 2 and 7 MIPS, respectively, which does not meet TUFFP requirements to process the amount of data analyzed by students. Also, HP has announced that it is concentrating its efforts on HP-UX and OSF, and eventually will stop Domain support.

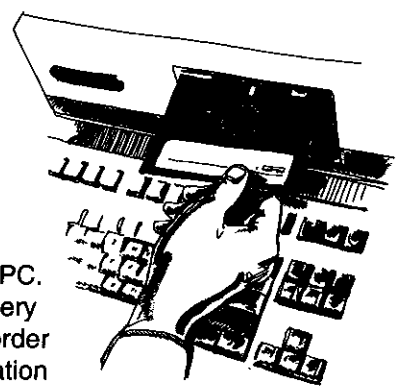
Earlier this year, HP announced the new 9000 series 700 work stations. The new series will run HP-UX and eventually, when OSF is completed, can run either operating system. The 730 processes at the speed of 76 MIPS and 72.2 SPECmarks. A 730 workstation with two color X-terminals, 1.3 GB disk, 1.3 GB DAT Tape, CD ROM, and other peripherals lists at $61,147. Since HP has given TUFFP the recognition of being a software developer, this opens the door for TUFFP to lease HP equipment at a monthly rate of 2 percent of list price instead of the normal 4 percent.

HP is offering a special deal to upgrade 4500 Apollo work stations to 5500s. This would increase the speed by 15 MIPS. This special offer only is available until September 30, 1991. The upgrade to the 5500 would run Domain and eventually, when OSF is completed, will be able to run either operating system. The upgrade would cost $12,000 plus about $7,500 a year in maintenance following the one-year warranty period.

TUFFP will complete its evaluation of these options and make a final decision in September. All concerns will be taken into consideration, including university policy, future computer usage, and industry standards.

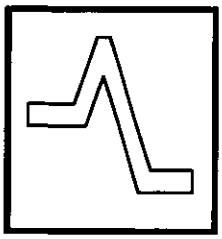
New 486 PC

TUFFP recently replaced a 286 PC with a new 486-33 MHz IBM compatible PC. The old 286 PC was constantly breaking down so the TUFFP Computer Committee recommended that it be replaced with a more reliable machine. The new 486 has a 200 MByte hard drive, 8 MByte RAM, 64 Cache, Logitech Mouse, extended keyboard, 3.5" and 5.25" disk drives, and Super VGA Panasonic monitor. The PC was purchased from the Vigor Company in Austin, Texas; with an educational discount, the purchase price was $3658. Now, TUFFP has a reliable PC which can be used to transfer files between the Macintosh and PC, and HP/Apollo workstations and PC. These connections are very important for TUFFP in order to maintain a communication line with the IBM PC world.

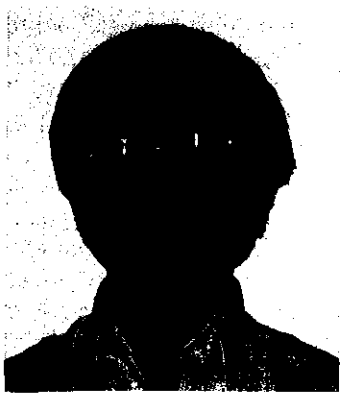


Removable Hard Drive

Because of the massive amounts of data collected by doctoral students, TUFFP needed more memory on the Macintoshes for data analysis. Removable hard drives are the solution to our memory problem. The removable hard drive is connected to the Macintosh through the SCSI port and uses removable cartridges. Each cartridge can store 44 MBytes of information and can be reused again and again. The cartridges act like a very large diskette. Once the cartridges are formatted, they appear as an icon and can be used as a diskette. It is highly recommended that these cartridges not be used as backup media due to reports from Mac magazines that the cartridges may crash if exposed to any kind of dirt or dust. Backups of all data will still be done on cassette tape. But, we are happy to report that we have not had a cartridge failure. Two Syquest removable drives were purchased from MacProducts for $998; each cartridge costs $72. With these drives, TUFFP has a source of "endless memory" that can handle as much data as students need to analyze.



Two-Phase Slug Flow in Hilly Terrain Pipelines



Gouhua Zheng

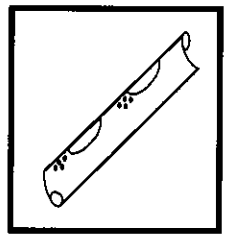
Two-phase flow in hilly terrain pipelines can cause significant practical operating problems. In this study, slug flow in hilly terrain pipelines was examined experimentally and theoretically. Extensive data were collected for slug flow in both Horizontal-Uphill-Downhill-Horizontal and Horizontal-Downhill-Uphill-Horizontal configurations in a 78 mm I.D., 420 m long pipeline. Complex physical phenomena were observed, including generation of pseudo slugs at pipeline connections, and changes in slug length and liquid holdup from one pipeline section to another.

A mathematical model was developed to simulate these phenomena. The model was based on a sink/source concept at the pipeline connections. A connection between two pipeline sections of different slopes was conveniently called an elbow. An elbow accumulates either liquid or void space as a sink, and the sink becomes a source when either liquid is released or void space is filled with liquid. The sink also has a characteristic capacity of its own. This capacity is positive if the sink has a function of accumulating liquid or negative if it only accumulates void space. This type of treatment effectively isolates flow upstream from an elbow from that downstream, while still allowing flow interactions between two adjacent pipeline sections.

The time-dependent, sink/source model allows detailed simulation of flow phenomena in hilly terrain pipelines. The model was simplified using assumptions of a uniform film thickness and equal slug front and bubble front velocities. Simplified equations were then obtained for both positive- and negative-capacity elbows. These easy-to-use equations are ideal for studying the effect of an elbow on slug flow characteristics in two adjacent pipeline sections. Good agreement was obtained between the simplified sink/source model and experimental data.

The overall effect of a hill or terrain on slug flow depends on the operating flow rates and pipeline geometries. For the special case of near-constant slug frequency corresponding to moderately high superficial liquid and gas velocities, this effect was found to be small except for pressure drop calculations, which must account for hydrostatic pressure recovery in downhill sections.

The proposed model and sink/source concept can be applied to two-phase flow in hilly terrain pipelines involving other flow patterns, especially the stratified flow. They also can be applied to field pipeline design, analysis, and slug catcher or separator sizing.



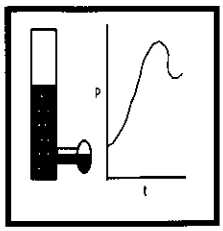
Slug Flow Phenomena in Inclined Pipes

Ibere Alves

Most methods for predicting pressure drop in gas-liquid two-phase flow in wellbores have been developed for vertical flow conditions. Application of these methods to predict the flow behavior in nonvertical deviated wells is inadequate and can result in substantial errors. This is due to the changes in the physical flow phenomena taking place in inclined pipes. In particular, the Taylor bubble rise velocity (drift velocity) changes significantly with the inclination angle, affecting the liquid holdup and pressure drop in the system.

This study focuses on the effect of the inclination angle on the Taylor bubble rise velocity. An experimental test facility has been designed and constructed, capable of rotating from horizontal to vertical. An extensive experimental program has been carried out on a 15 meter long, 5 cm diameter test section, utilizing a new computer-based data acquisition system. Detailed information of the flow phenomena has been obtained. Measurements of the Taylor bubble rise velocity under flowing and stagnant liquid column conditions, and the corresponding pressure and liquid holdup distributions have been acquired for all inclination angles between vertical (90°) and horizontal (0°).

A new mechanistic model has been developed for the prediction of the Taylor bubble rise velocity. The model is an extension of the Benjamin analysis for the horizontal case to the inclined and vertical cases, taking into account surface tension effects. The proposed model is applicable for the entire range of inclinations, from horizontal to vertical. Good agreement is observed between the experimental data and the proposed model.



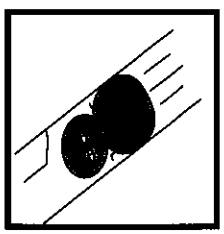
Transient Drift Flux Model for Wellbores

Metin Gokdemir

A model for predicting transient two-phase flow behavior in wellbores has been developed. The model consists of a drift flux formulation based on two-phase flow equations derived using cross sectional area averaging. It has been shown that the proposed drift flux model is stable and well posed.

The model is solved numerically by utilizing a staggered grid, subdividing the flow field into cells. The drift flux balance equations are approximated inside the cell or at the cell boundaries. The resultant linear system of equations are solved simultaneously by a direct inversion method.

Sample simulation runs are presented to demonstrate the capabilities of the model. The results show that the model can be applied to analyze a wide range of transient two-phase flow problems encountered in the petroleum industry.

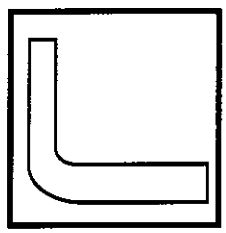


Transient Flow and Pigging Dynamics in Two-Phase Pipelines

Kazu Minami

The knowledge of the flow characteristics of a two-phase pipeline under transient flow or pigging operation is essential for a proper design and operation of the pipeline and the upstream and downstream facilities. An existing simplified model for predicting two-phase transient flow behavior that uses physically based, flow pattern-dependent mechanistic models has been modified and improved. Also, a new pigging model to simulate the dynamics of pigging operation has been developed. The resulting set of differential equations is solved numerically utilizing a mixed Eulerean-Lagrangean approach. The discretization of the transient model equations are performed using an Eulerean (fixed) coordinate grid system, and the pigging model equations using a Lagrangean (moving) grid system. The computer simulator that couples the transient model and the pigging model is capable of predicting the overall flow behavior of a two-phase pipeline under transient condition, with or without pigs.

An extensive experimental program has been carried out to acquire two-phase transient flow and pigging data on a 420 m (1,378 ft) long, 77.9 mm (3.068 in) diameter horizontal pipeline. A computer based data acquisition system has been utilized to obtain rapidly changing and detailed information of the flow behavior during the transient tests. Pressure, in-situ liquid holdup, translational velocity and flow pattern changes were monitored at four measurement stations installed along the pipeline. Comparisons of the predictions of the numerical model against the experimental data show that the proposed simplified transient model and the pigging model are well suited for simulating the type of transient behavior observed in two-phase pipelines in the petroleum industry.



Two-Phase Flow in Horizontal Wells

Masaru Ihara

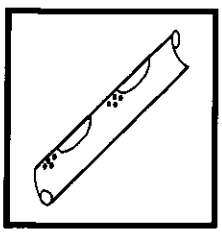
An experimental and theoretical investigation of the flow behavior in horizontal wells and its interaction with the reservoir was performed. This has been recognized as one of the unsolved, yet most important problems in the production area.

A new test facility was designed and constructed, suitable for acquiring data on the relationship between the pressure drop along the well and the fluid influx from the reservoir. Pertinent preliminary data were acquired.

Initial models are proposed which describe the flow behavior in a horizontal well configuration for both the experimental work and field operations. The models use the IPR (Inflow Performance Relationship) approach, the black oil model and mechanistic models for wellbore hydraulics.

Good agreement was found between the model for the experimental work and the preliminary experimental data.

A new IPR apart from the extension of the Darcy's law must be investigated extensively to help in the proper design of horizontal wells.



Slug Flow in Extended Reach Directional Wells

Hector Felizola

Since the last Advisory Board meeting, the test facility previously used to investigate slug flow phenomena in inclined pipes was carefully checked for any operating problems and preliminary runs have been conducted. These include the following:

- Calibration of capacitance sensors
- Installation and calibration of temperature transducers
- Calibration of pressure transducers in both the test section and the metering section
- Calibration of orifice meters using a sonic nozzle
- Rearrangement of the data acquisition system to include new signal reading capabilities, in addition to the existing eight signals
- Study of the pumping system and determining the main characteristics of the pump needed to work in the slug flow area.
- Modifications to test section (enlargement of inlet pipe for smaller inclination angles - 0 - 30°)

Efforts have been made to learn the LabView data acquisition system. Software has been developed for measurement and regulation of phase superficial velocities and data acquisition. Also, flow pattern maps have been generated for each inclination angle from horizontal to vertical at increments of 10°. Data acquisition is expected to begin by mid-September. Preliminary results will be presented at the November Advisory Board meeting.

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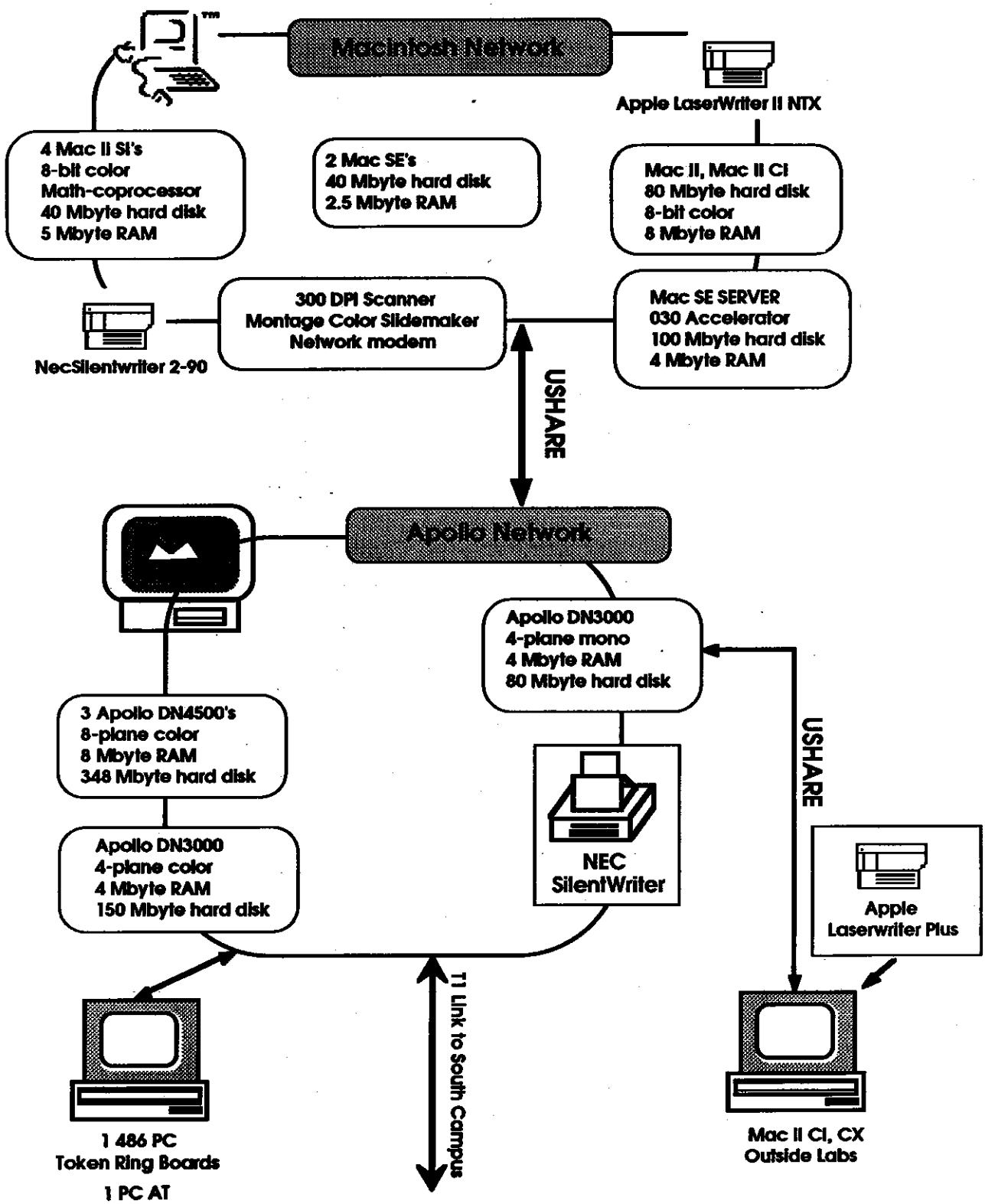

TUFFP Computer Network

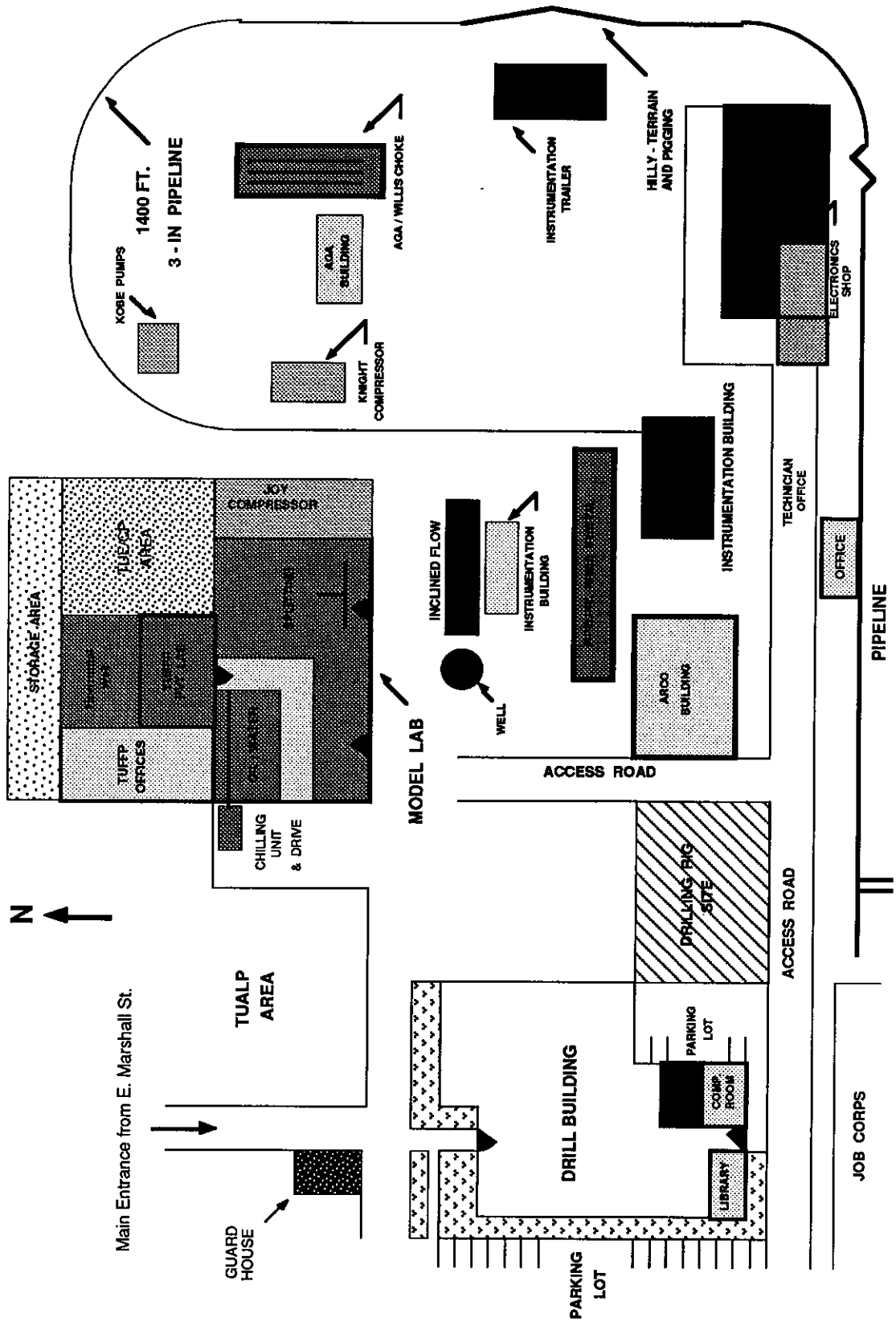

Illustration of TUFFP Test Facilities

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