

TULSA UNIVERSITY
FLUID FLOW PROJECTS

NEWSLETTER

August, 1983

ADVISORY BOARD MEETING

The Fall, 1983 TUFFP Advisory Board meeting will be held at the Sheraton Airport Inn in Tulsa, Oklahoma on Tuesday, November 8, 1983. The meeting will begin at 8:30 a.m. and adjourn at 4:30 p.m. Please note the 30 minute earlier starting time than for previous meetings. A pre-meeting cocktail party will be held in the same hotel from 5:00 - 7:00 p.m. on Monday, November 7, 1983. Members wishing to tour TUFFP test facilities are urged to do so Monday afternoon.

An Advisory Board meeting brochure will be mailed to all members prior to the meeting. It will contain sufficient information to prepare each attendee for active participation in discussions on current and future research projects, financial matters and operating procedures.

A REQUEST FOR INFORMATION form will be mailed to all members on October 11, 1983 to determine attendance at the meeting.

STATUS OF RESEARCH PROJECTS

HORIZONTAL SLUG FLOW MODELING/METERING (Kouba)

The summer has been spent concentrating on two main areas: preparing the 1400 ft long pipeline facility for testing; and, continued testing and investigating of two-phase flow instrumentation. Preparing the pipeline facility included the following:

- 1) construction of a computer pipeline building to house sensitive equipment and the data acquisition system. The building is located at test station 3 where the pipeline passes through the observation room.
- 2) replacement of instrument and power cables along the pipeline.
- 3) installation of field and computer patch panels to allow convenient access to all signals.
- 4) addition of a quick-closing valve upstream of test section 3 and improved switch control.
- 5) surveying and leveling the pipeline.
- 6) installation of liquid and gas turbine meters on single phase supply lines.
- 7) installation of coalescing filters on kerosene tank and air supply lines.

Work on instrumentation included:

- 1) reconditioning all pipeline pressure ports, transducers and demodulators.
- 2) design, construction and testing of a more stable capacitance sensor configuration.

- 3) installing graduated slide mounts for positioning the optical and CTA probes.
- 4) design and construction of semi-portable nuclear densitometers.
- 5) investigating Laser Doppler Anemometry systems of TSI, DISA and OEI for possible two-phase flow applications.

PERFORMANCE AND CALIBRATION OF CTA PROBE (Sadeghzadeh)

Work on this project has been completed and a final report will be distributed to members in September, 1983.

ANALYSIS OF PLUNGER LIFT DYNAMICS (Rosina)

Final data analysis and model development is nearing completion. A draft of a final report has been submitted for editing. Distribution of a final report to members is scheduled for October, 1983.

TWO-PHASE FLOW THROUGH CHOKES (Sachdeva)

Data collection involving air-water and air-kerosene mixtures has been completed. About 240 tests were conducted for an air-water mixture and approximately 300 for an air-kerosene mixture. Recall that the chokes were installed horizontally and were free from effects of bends/elbows and the choke housing.

The data are now being compared with existing correlations. The following table summarizes how air-water data compared with existing correlations.

| <u>Correlation</u> | <u>Flow Type</u> | <u>Average Error</u> | <u>Standard Deviation</u> | <u>Absolute % Error</u> | <u>Comparison Basis</u> |
|--------------------|------------------|----------------------|---------------------------|-------------------------|-------------------------|
| Pilehvari | Critical | -18.10 | 16.51 | 22.20 | Pressure |
| Ashford | Critical | 36.70 | 7.65 | 36.10 | Liquid Rate |
| Achong | Critical | -5.70 | 19.03 | 16.90 | Pressure |
| Ros | Critical | -25.10 | 13.76 | 26.10 | Pressure |
| Gilbert | Critical | -71.72 | 22.18 | 71.72 | Pressure |
| Omana | Critical | 59.22 | 6.40 | 59.22 | Pressure |
| Pilehvari | Subcritical | -16.73 | 39.70 | 24.72 | Press.Drop |
| Pilehvari | Boundary | 6.50 | 16.19 | 11.15 | Press.Drop |

A similar analysis will be done with the air-kerosene data. Development of empirical or semi-empirical correlations is planned for critical, boundary and subcritical flows.

A draft of a final report is anticipated in September. Distribution to members is scheduled for October, 1983.

TWO-PHASE FLOW SPLITTING AT A TEE (Shoham)

Data acquisition for a regular (2 in. x 2 in.) horizontal tee has been completed. Over 100 experimental runs were carried out in stratified smooth, stratified wavy and annular flow patterns. The data include splitting flow ratios and pressure gradient curves for the branch and for the run arms.

Data analysis shows a strong dependence of the splitting phenomenon on the flow pattern existing upstream of the tee. This dependence includes the liquid phase flow preference as well as the pressure gradient in the tee arms.

- a) Preferential liquid flow: The liquid phase tends to flow into the run arm in stratified smooth flow and into the branch arm during annular flow. For stratified wavy flow, this depends on the liquid flow rate. At low liquid flow rates the liquid phase preferentially flows into the branch arm. At high liquid flow rates the liquid phase preferentially flows into the run arm.
- b) Pressure gradients at the tee: Pressure gradients in the run and branch arm were measured with a pressure transducer and recorded on a chart recorder. The following can be concluded from the data.

For stratified smooth flow, the pressure gradients are negligible due to the low gas flow rate and low phase velocities.

During stratified wavy and annular flow, the following behavior of the pressure gradients is observed. At the branch arm inlet (tee exit), there is a sharp pressure drop (maybe due to secondary flow effects) and then there is a gradual pressure recovery until steady state pipe flow conditions are reached. In the run arm, due to the lower gas flow rates and lower velocities, there is an increase in the static pressure to a value above the flowing pressure upstream of the tee. These effects are more pronounced for annular flow than for stratified wavy flow. Also, the extent of the pressure drop in the branch arm and the pressure rise in the run arm depends on the branch gas fraction intake.

The "Film Inversion Model" presented at the last Advisory Board meeting is based on competing inertia and centrifugal forces at the tee. Efforts are underway to improve the prediction of this model for stratified flow. Future work will include extension of this model to annular flow.

TRANSIENT PHENOMENA IN TWO-PHASE PIPELINES (Dutta-Roy)

A comprehensive flow pattern-dependent model for simulating unsteady state two-phase flow behavior in horizontal pipelines has been developed. The equations of mass and momentum conservation in each phase have been formulated separately for the homogeneous, stratified and annular flow patterns. The Taitel-Dukler analytical flow pattern prediction model has been used as the criterion for switching from one equation set to another.

The 1400 ft long, 3 in. diameter pipeline is presently being modified to permit generating transient flow data. Continuous, time-dependent pressure and volumetric phase fraction readings from several locations along the pipeline will be monitored with transducers and capacitance sensors. Flow rates at both inlet and outlet ends will be monitored at all times. It is anticipated that data collection will be completed in September, and a draft of a final report submitted for review by late September. Distribution of a final report to members is scheduled for October, 1983.

MODELING TRANSIENT TWO-PHASE FLOW (Sharma)

Since the May, 1983 Advisory Board meeting, the following have been accomplished:

- 1) Completion of a report titled "Modeling Transient Two-Phase Flow in a Stratified Flow Pattern". The report was mailed to members in August, 1983.
- 2) An independent study was conducted in the area of single phase transients. Emphasis was placed on applying the method of characteristics to numerically solve unsteady fluid flow problems. The textbook "Fluid Transients" by Wylie and Streeter was used.

Upon completion of item 2 above, a literature search was begun to seek information pertaining to the slug flow regime. A substantial amount of material was found and presently a literature review is being conducted. Future work includes:

- 1) development of a mathematical model to describe transient two-phase slug flow;
- 2) application of a numerical method to solve the mathematical model; and
- 3) experimental verification of the model.

TWO-PHASE FLOW THROUGH AN ANNULUS (Caetano)

The objectives of this project are to investigate flow pattern, liquid holdup and pressure drop for two-phase flow through a concentric vertical annulus. An experimental system has been designed to meet these objectives. The system consists of an external acrylic pipe with a 3 in. I.D. x 3.5 in. O.D. to simulate the casing, and a 1.66 in. O.D. x 1.25 in. I.D. internal PVC pipe to simulate the tubing. The two-phase mixture will flow in the annular space between the pipes. The total length of the test section is 48 ft.

Data acquisition will be carried out as follows:

- 1) Flow pattern will be determined visually.
- 2) Liquid holdup will be measured with a set of quick closing ball valves and with a capacitance sensor.
- 3) Pressure drop will be measured with Validyne pressure transducers.

All data will be taken with both water and kerosene as the liquid phase and using air as the gas phase.

The system is now under construction. The test facility will be mounted on the superstructure used by Mukherjee for a previous inclined pipe flow study. Data acquisition will begin at the end of September, 1983. A final report is scheduled for February, 1984.

EQUIPMENT AND FACILITIES

Major modifications have been made to the 1400 ft long pipeline flow system and were described in the slug flow progress report.

The move of the Engineering College to Keplinger Hall on the South Campus was completed during the summer. The following is a result of the move:

- 1) An electronics/instrumentation laboratory must be established in the Drill Building to replace the one used in Jersey Hall. The laboratory will be shared by TUFFP and TUALP. A calibration facility for transducers and demodulators has been developed.
- 2) A restocking of tools will be necessary since many of the tools shared with the College will no longer be available.
- 3) Installation of a security fence and changing the entrance to the North Campus from Lewis to a North entrance will be implemented during the Fall, 1983.

- 4) New office furniture was ordered for the TUFFP Director and Administrative Assistant for the offices in Keplinger Hall. Each will be maintaining an office on both campuses.
- 5) TUFFP has leased a Sharp SF-781 duplicating machine for the North Campus.
- 6) TUFFP, TUDRP AND TUALP have jointly leased a telex machine to improve communications with international members. The new telex number is 747135, TUDRALFF.

A CPT 8525 word processor and Rotary VIII printer have been purchased. Work will be transferred to the CPT as training permits.

One of the Keplinger companies donated a variety of electronic equipment to Tulsa University. As a result, TUFFP received an HP 9825A computer with several ROM cartridges, an HP9872A plotter, and several D/A converters and preset counters. An HPIB interface has been ordered to permit using the plotter with the Harris and Honeywell computers. This will provide the needed graphics improvements for TUFFP without having to purchase a new plotter.

Purchase of computer time for consulting projects has provided funds to pay for part of the maintenance fee for the Harris computer. As a result, TUFFP will not have to use all of the \$10,000 budgeted for computer use in 1983. A request has been made to a TUFFP member to donate peripheral equipment to enhance the Harris computer.

No plans have been made to begin an upgrading of the test facility for conducting oil/water flow tests. Discussions have been initiated with a TUFFP member to do extensive testing of oil water mixtures on a contract basis. The testing would result in making all desired improvements in the pipe viscometer flow loop.

PERSONNEL

Mr. Elisio Caetano, an M.S. candidate from Brazil, and an employee of Petrobras, selected the topic "Vertical Two-Phase Flow Through an Annulus" for his thesis. Since this topic is of interest to TUFFP members and since no research assistantship support from TUFFP was required, a decision was made for TUFFP to support the experimental program involved.

An engineer from France sponsored by ELF Aquitaine, Mr. Jean Claude Goyon, will arrive in November for a two-phase flow training program in TUFFP. It is anticipated that he will also pursue an M.S. degree program.

An Undergraduate Research Internship scholarship supported by TUFFP has been offered Mr. Jay Edmondson. Mr. Edmondson is a Senior in Chemical Engineering and has worked for TUFFP the past two summers. He will continue working with Gene Kouba on slug flow research for his B.S. Thesis and plans to pursue an M.S. degree starting in May, 1984.

Dr. S. Banerjee has agreed to provide a seminar on transient two-phase flow as part of the TUFFP seminar program established last year.

Dr. Mohan Kelker joined the Petroleum Engineering Faculty in the Fall, 1983 and has shown an interest in the TUFFP program. His Ph.D. research at the U. of Pittsburgh was in two-phase flow.

Dr. Ovadia Shoham, a TUFFP Research Fellow, is offering a graduate course at Tulsa University this Fall on Two-Phase Flow Modeling. All TUFFP research assistants are enrolled in the course.

Dr. Y. Taitel will spend approximately 2 weeks with the TUFFP research staff in September. He will assist in formulating better approaches to model transient slug flow, two-phase splitting and flow patterns in a vertical annulus.

MEMBERSHIP

Confirmation has been received that Nippon Kokan K.K. and Britoil will join TUFFP. It is assumed that their membership will be effective for 1983. No previous members that terminated membership for 1983 have reinstated membership. Companies that have expressed an interest in TUFFP include: ADMA-OPCO, Atkins Research and Development, Bidas, Creare, JGC Corp., Japan Oil Energy Co., Natural Gas Pipeline Co. and TransCanada Pipeline Co. In addition, two research consortiums, bhra fluid engineering and HTRI have inquired about possible collaboration.

FINANCIAL

Expenditures are slightly above the April 1, 1983 budget revision given in the May Advisory Board meeting brochure. Increases reflect slight extensions in completion dates for three research projects, increased student labor and consultant charges to maintain schedule on the slug flow project, and expenditures for the two-phase flow in annulus project. Projected 1983 expenditures are now \$383,000. The two new members would more than offset the increased expenditures.

Invoices for \$10,000 1984 membership fees will be mailed to all members in October, 1983. Payment by early 1984 would be appreciated to permit identifying delinquent members as soon as possible. Two members have not yet paid 1983 membership fees. Any members contemplating a termination of their membership for 1984 are urged to abide by the October 1 notification deadline.

MISCELLANEOUS

Responses to the 1983 TUFFP Questionnaire have been received from 22 of the 38 members. The following table summarizes the number of responses for item 1 of the Questionnaire dealing with ranking member interests on individual projects.

| Project | Level of Interest | | | |
|--|-------------------|------|--------|-----|
| | Very High | High | Medium | Low |
| 1. Oil-Water Flow | 8 | 5 | 5 | 3 |
| 2. Flow in Annulus | 2 | 5 | 9 | 5 |
| 3. Slug Flow | 7 | 10 | 3 | 1 |
| 4. Two-Phase Splitting | 6 | 5 | 9 | 2 |
| 5. Transient Two-Phase Flow | 3 | 9 | 7 | 2 |
| 6. Flow Through Piping Components | 4 | 4 | 11 | 3 |
| 7. Flow Through Willis MOV's | 2 | 5 | 3 | 10 |
| 8. Slug Catcher/Separator Modeling | 7 | 7 | 6 | 1 |
| 9. Multiple Line Manifolding | 5 | 7 | 8 | 1 |
| 10. Modeling Blowout Behavior | 0 | 3 | 7 | 10 |
| 11. Flow Through Hilly Terrain Pipelines | 8 | 7 | 4 | 2 |

Six members have expressed an interest in having a TUFFP short course in London and would enroll approximately 12 persons. Preferred dates appear to be late June or late July, 1984. A decision will be made at the November Advisory Board meeting on whether to hold the course, the location, and dates. bhra fluid engineering has offered to assist in selecting the best location in or near London for such a course. Tentative reservations will be made, if necessary, to assure space availability.

Requests have been received for 14 magnetic tapes of the TUFFP transient programs and for 15 magnetic tapes of the program for simulating separator behavior under slug flow conditions. Tapes will be mailed in mid September.

Several companies have expressed an interest in having another TUFFP short course on "Two-Phase Flow in Pipes" in Tulsa next May, perhaps as a replacement for the Research Application Conference (RAC). Holding an RAC requires significant preparation from the TUFFP research staff. Having both an RAC and a short course in Tulsa would seriously detract from the research program. Members will be asked to vote at the November Advisory Board meeting on which of the two programs they want to be held. Tentative reservations have been made at a Tulsa hotel for May 9-11, 1984 for the RAC or May 21-25, 1984 for a short course.

