T U P D P

Tulsa University Paraffin Deposition Projects

Director
Cem Sarica (918) 631-5154
cem-sarica@utulsa.edu

Co-Principal Investigator
Mike Volk (918) 631-5127
michael-volk@utulsa.edu

Director Emeritus
James P. Brill (918) 631-5114
brill@utulsa.edu

Project Coordinator
Linda M. Jones (918) 631-5110
jones@utulsa.edu

Faculty Associate
Holden Zhang (918) 631-5142
hong-quan-zhang@utulsa.edu

Senior Research Associate
Emmanuel Delle-Case (918) 631-5109
emmanuel-delle-case@utulsa.edu

Research Associates
Hong Chen (918) 631-5137
hong-chen@utulsa.edu
Qian Wang (918) 631-5107
qian-wang@utulsa.edu

Research Technicians
Scott Graham (918) 631-5147
sdgraham@utulsa.edu
Craig Waldron (918) 631-5131
craig-waldron@utulsa.edu

Research Assistants
Francis Anosike (918) 631-5143
francis-anosike@utulsa.edu
Antonio Bruno (918) 631-5143
antonio-bruno@utulsa.edu
Gladys Sucre (918) 631-5144
gladys-sucre@utulsa.edu

Fax Number: **(918) 631-5112**
Web Address: **www.tupdp.utulsa.edu**

February 2006 **Volume 2, Issue 1**

Executive Summary

The development of the new TUWAX (WAXPRO) is in the final stage. The beta version of the TUWAX (WAXPRO) software has been posted to the website. Efforts are underway to make TUWAX (WAXPRO) CAPE-OPEN standard compatible.

Preliminary bench top paraffin deposition studies using a rectangular test cell showed that changes in the flow rate did not have an impact on the amount of wax that was incorporated into the deposit for tests conducted with oil temperature above WAT. The deposit thickness decreased and the wax content of the deposit increased as the flow rate increased. The film mass transfer model performed better than the equilibrium model for all cases studied. Both the equilibrium and film mass transfer models performed better when the experimental data for wax content were used to vary the deposit wax content with time. The results also indicate that the aging model needs to be modified to incorporate a way to predict the aspect ratio of the deposit under different conditions, since the correct prediction of deposit aging was shown to be critical for the model performance. The research results are detailed in Ms. Gladys Sucre's MS thesis which is posted on the TUPDP website. The tests with oil temperatures below WAT are underway. The results will be presented at the upcoming Advisory Board meeting.

The small scale facility was modified to include a canopy to reduce the effects of sunlight on the test sections and storage tank. A new electric motor was installed in place of the hydraulic system. The cold finger apparatus was recommissioned. Cold finger experiments were started on South Pelto and will be followed by Blake crude oil.

Experiments for transportation force and for breaking force were completed. Test with three different wax plug lengths (14 in., 23 in., and 32 in.) and three oil contents (70%, 50% and 30%) were tested. Tests with a bypass pig were also completed. The results will be reviewed at the upcoming Advisory Board meeting.

TUPDP Membership

Phase 3 of the Tulsa University Paraffin Deposition Projects (TUPDP) began on April 1, 2004. We currently have 14 members with the recent loss of Unocal due to merger. There are continuing discussions with DOE and Sintef regarding membership in TUPDP.

Invoices for the 2006 membership fees were mailed to member companies in February 2006.

TUPDP Members

Baker Petrolite	**BG**
BHP Billiton	**BP**
Chevron	**ConocoPhillips**
ExxonMobil	**JOGMEC**
Marathon Oil Company	**Nalco**
Petrobras	**Shell**
Statoil	**TOTAL**

Meetings / Conferences

Spring 2006 Advisory Board Meetings

Plans have now been finalized for the Spring 2006 Advisory Board meetings. The TUHFP JIP, TUPDP Advisory Board meetings, the TUFFP/TUPDP reception, and the TUFFP Advisory Board meeting will all be held on the University of Tulsa Campus in the Allan Chapman Activity Center. The TU Hydrate JIP (TUHFP) Advisory Board meeting will be held on Tuesday, March 28th. The meeting will begin at 8:00 a.m. and adjourn at approximately 2:45 p.m. A tour of the test facilities will follow the TUHFP meeting at 3:00 p.m. on the University of Tulsa North Campus. Following the tour, there will be a joint TUHFP/TUPDP/TUFFP BBQ between 5:00 - 7:00 p.m. The TUPDP Advisory Board meeting will be held on Wednesday, March 29th. The meeting will begin at 9:15 a.m. with breakfast at 8:30. The meeting will adjourn at approximately 4:00 p.m. Following the TUPDP meeting, there will be a joint TUFFP/TUPDP reception from 6:00 - 9:00 p.m. The TUFFP Advisory Board meeting will begin at 8:30 a.m. on Thursday, March 30th with breakfast at 8:00 and will adjourn at approximately 4:30 p.m. The Request for Information form and hotel information will be placed on the web page soon. All persons from your company that plan to attend the Advisory Board meetings, should complete and return these forms as soon as possible to help us plan the meetings. Information on the Advisory Board meetings can also be found on our web site. You can then follow the links for the Request for Information form. TUFFP Advisory Board meeting brochures will be available for members at the meeting and a concerted effort will again be made to have the combined brochure and slide copy available for downloading from the web site shortly before the meeting. The brochure will contain sufficient information to help each attendee actively participate in discussions on current and future research projects, financial matters, and operating procedures.

BHRg's 5th North American Conference on Multiphase Technology to Be Held in Banff, Canada

BHR Group's 5th North American Conference on Multiphase Production Technology is scheduled to be held between May 31 and June 2, 2006 in Banff, Canada. This conference is co-sponsored by Neotechnology Consultants of Calgary, Canada, and TUFFP. It brings together experts from across the American Continents and Worldwide. The conference will benefit anyone engaged in the application, development and research of multiphase technology for the oil and gas industry. Applications in the oil and gas industry will also be of interest to engineers from other industries for whom multiphase technology offers a novel solution to their problems. The conference will also be of particular value to designers, facility and operations engineers, consultants and researchers from operating, contracting, consultancy and technology companies.

Over 40 papers in various multiphase flow and flow assurance subjects will be presented at this conference. The detailed information about the conference can be found on BHRg's web site www.brhgroup.com.

TUFFP Short Course

The 31st TUFFP "Two-Phase Flow in Pipes" short course is scheduled to be taught May 15-19, 2006 in Tulsa by Dr. Sarica and Dr. Brill. The course covers the most current, up-to-date-research performed at the TUFFP and TUPDP. This five-day course is focused on the fundamentals of two-phase flow in piping systems encountered in the production and transportation of oil and gas. The short course will include a half-day session on paraffin deposition in pipes. For this short course to be self sustaining, at least 10 enrollees are needed. We urge our TUFFP and TUPDP members to let us know soon if they plan to enroll people in the short course. Information regarding the short course and online registration can be found at http://www.cese.utulsa.edu/coursedetail.jsp?id=53.

Progress Updates

Project 1 - Single Phase Studies

Investigation of Single-Phase Paraffin Deposition

Gladys Sucre

Objectives

The objective of the study is to investigate the paraffin deposition phenomenon under single-phase conditions. Specific objectives of this study are: design and construct a bench-top paraffin deposition test facility; and execute a preliminary experimental program to investigate the shear effects.

Introduction

Single-phase paraffin deposition has been extensively investigated. The performance of available models to predict the deposition phenomenon was evaluated by performing both a sensitivity analysis and a validation study making use of existing experimental data.

A new test facility was designed and constructed. Preliminary single-phase deposition tests were conducted with a mixture of mineral oil, kerosene and candle wax. The tests were designed to determine the dependency of the deposition process on flow rate and flow regime and to obtain aging data with time. The oil temperature was above the wax appearance temperature for all tests.

Conclusions

A rectangular duct test section with an aspect ratio of 3:1 was constructed. The commercial computational fluid dynamic simulator FLUENT was used to study the thermal and hydraulic profiles of possible test sections and to aid in the facility design.

The study showed that changes in the flow rate did not have an impact on the amount of wax that was incorporated into the deposit. The deposit thickness decreased and the wax content of the deposit increased as the flow rate increased.

The film mass transfer model performed better than the equilibrium model for all cases. The final thickness values predicted were always lower than the ones obtained experimentally. This is speculated to be due to the over-prediction of the surface temperature, possibly because of a lower convective heat transfer coefficient. Accurate heat transfer calculations are shown to be a key parameter when the temperature of the oil is above WAT.

The Singh et al. aging model predicts a rapid wax content growth and stabilization in approximately six hours. The experimental wax content data shows a slow rate of aging at the beginning of each test with stabilization of the wax content after twelve hours.

Both the equilibrium and film mass transfer models performed better when the experimental data for wax content were used to vary the deposit wax content with time. The performance of the models is strongly dependent on the final predicted wax content when using the Singh et al. aging model. A correct prediction of deposit aging has been found to be crucial to obtain good thickness predictions.

Recommendations

A heat flux sensor should be installed on the cold plate to avoid the calculation of heat transfer coefficient. This will minimize the dependence of the deposit growth model on the heat transfer calculations.

It is recommended that tests with a similar test matrix to that used in this study should be performed with different temperature differences (between oil and cold plate), and below the wax appearance temperature in order to corroborate if the mass of wax in the deposit remains almost constant with changes in flow rate.

The aging model needs to be modified to incorporate a way to predict the aspect ratio of the deposit under different conditions, since the correct prediction of deposit aging was shown to be critical for the model performance.

Software Development

Hong Chen

Objective

The objective of this project is to develop a user-friendly wax deposition software which incorporates state-of-the-art deposition models

Improvement of Current MSI-TUWAX Software

The current MSI-TUWAX was maintained during the last

quarter of 2005. The improvements are as follows: 1) Discontinuity of the liquid holdup and flow pattern oscillations in transition region between stratified and slug flows in multiphase deposition routine are corrected; 2) a bug on the total wax deposit volume calculation considering the flow pattern effect for multiphase deposition routine is identified and fixed; 3) Two ways of identifying the version of executable file are implemented (the latest version of executable files is 2.2.3). These improvements are also incorporated in our new Excel based software as well.

Development of New Software with Excel GUI

The development of the new TUWAX is in the final stage. The beta version of the new TUWAX software will be available in January 2006. Currently, the plotting function of this new software is still under development. The simulation results are now saved in a text file to be used in personalized graphic generation.

Effort to Make TUWAX CAPE-OPEN Standard Compatible

Some TUPDP companies have shown strong interest to make TUWAX CAPE-OPEN compliant. CAPE-OPEN is a set of protocols that defines rules and interfaces that allow computer-aided process engineering (CAPE) applications or components to interoperate. CAPE-OPEN has the promise of PLUG and PLAY. A specific software can be plugged into another software and run if the specific software and another software are CAPE-OPEN complaint. For example, TUWAX can be used with other CAPE-OPEN compatible software for the thermodynamic & physical properties calculation, and TUWAX could be incorporated into CAPE-OPEN standard compatible process software. Making TUWAX Cape-Open standard compatible is expected to increase the use of TUWAX and benefit our membership.

CAPE-OPEN is currently maintained, revised and promoted by CAPE-OPEN Laboratories Network (CO-LaN) which is a neutral industry and academic association promoting open interface standards in process simulation software. More detailed information on CAPE-OPEN is available at www.co-lan.org. University of Tulsa is in the process of being an associate member of CO-LaN.

Project 2 - Multiphase Flow Studies

Two-Phase (Oil-Water) Paraffin Deposition

Antonio Bruno

Objective

The main objective of this study is to identify the effects of water in paraffin deposition phenomena and develop an oil-water paraffin deposition model.

In order to achieve the objective, the following tasks were identified and are being performed:

- Develop a preliminary oil-water deposition model based on the TU Single-Phase model.
- Validate this preliminary model by conducting a series of experiments using different crude oils.
- Propose improvements to this preliminary model and establish a new enhanced model.

Introduction

At the 11th Semi-Annual Advisory Board Meeting[1], a discussion about previous single-phase test results obtained in the small scale loop with South Pelto Crude Oil showed the need for further verification of these experimental data. Several fluctuations in the differential pressure measurements were observed, these fluctuations made the thickness calculations using the pressure loss (Δp) method unreliable. These fluctuations have coincided with cyclical changes in ambient temperature and sunlight conditions. Several modifications have been started on the Small Scale Loop to ensure that the effects of ambient temperature and sunlight are minimized.

Facility Modification

Canopy Installation

A canopy has been designed to reduce the effects of sunlight on the test sections and storage tank. This design has already been approved by TU's Physical Plant. The plans have been submitted to the contractor and work has already begun by installing the metal posts that will hold the canopy itself. Construction should be completed by February 2006.

Electric Motor

While conducting single-phase experiments using South Pelto Crude oil, the fluctuations observed could not be attributed to any changes in density or viscosity of the fluid itself. These parameters, as well as flow rate remained constant during the experiments. Nevertheless, the pumping system was driven by a hydraulic motor which uses lubricant oil. This oil could be expanding due to changes in ambient temperature thus modifying the rotational speed of the shaft. Even though there are no sensors that can verify this phenomenon, it has been identified as a probable cause for the pressure fluctuations.

To avoid this interference, a new electric motor is being installed in place of the hydraulic system. This new motor will be fitted with a variable speed drive that will provide greater flowrate control using the existing Lab View module.

Blake Crude Oil

Preliminary DSC analysis on Blake Flank shows a WAT of 90 °F and 4% wax content by weight. Viscosity at 60 ° F is 30.6 cp and 19.7 cp at 100 °F.

Cold Finger Experiments

The cold finger apparatus is being recommissioned. New magnets have been installed. A new chiller has been purchased. Starting January 23rd, cold finger experiments will start on South Pelto followed by Blake crude oil.

Conclusions and Future Work

Once the cold finger apparatus has been recommissioned, two sets of cold finger experiments will be performed. These experiments should be completed by January 31st.

The next experimental phase will start on February with oil-water experiments performed on South Pelto crude oil. Blake crude oil experiments will follow and should be completed by March 15th in time to be presented at the 12th Advisory Board Meeting.

Project 3 Pigging Studies

Qian Wang

Objectives

It is desired to determine the pigging frequency accurately so that pigs will not be stuck in the line or to prevent unnecessary pig runs. The available tools in the literature or commercial software have been found inadequate. Pigging frequency is primarily controlled by the wax deposition rate, pigging efficiency and the required force to run a pig in the line. The wax deposition rate or thickness can be predicted by the wax deposition models. Therefore, the primary objective of the pigging studies is to develop a predictive model to determine the required force to keep the pig mobile.

Background

The pigging project has four tasks, which are outlined in the proposal. Two of the tasks literature review and feasibility study have already been completed.

The feasibility results indicated that the only available model for the transportation of cut wax did not perform well when compared with available flow loop and laboratory data. Moreover, a simplified pigging transport model was proposed based on the available data. Both the spring 2005 Advisory Board Meeting discussions, and the ensuing communications with member companies, established that an investigation of by-pass pigs was of interest as well as the regular disc or cup pigs. Therefore, a pigging experimental study was started.

The specific objectives of the experimental studies are to determine the relative contributions of each of the following forces during a pigging run and investigate the effect of pig type (by-pass vs. non bypass) on the relative importance of each force (pushing vs. cutting).

Experimental Study

As presented in fall 2005 Advisory Board meeting, a new pigging test facility was already designed and commissioned. A Schematic of the facility is shown in Figure 1. The test section consists of upstream section, two spool pieces and down stream section, as shown in Figure 2.

Disc pig and by-pass disc pig are selected for this project. Pigs are provided by TD Williamson Company.

Pigging Tests

Pigging tests are designed to measure the wax breaking

force and transportation force. Experiments for transportation were completed and the experiments for breaking force are under going.

Transportation Force Test

Melted candle wax was pour into the spool piece to create a wax plug. When the wax plug was cooled completely, the spool piece was mounted to the test loop. The wax plug was pushed with oil, and the pressures along the test section were measured. These pressures are expected to reveal wax plug transportation force information.

Three different lengths (14 in., 23 in., and 32 in.) and three oil contents (70%, 50%, and 30%) were tested The data processing and analysis is underway

Breaking Force Test

To measure the breaking force, a wax layer is cast on the pipe wall with different wax thicknesses. Once the spool pieces cast with a wax layer, they are mounted on the test section. Pig is pushed through the pipe by oil.

Although there is no straight forward procedure for wax casting, a great effort is given and a way to cast a desired wax layer within the spool piece is found.

The tests with wax thicknesses of 2, 4 and 6 mm and oil contents of 70, 50, and 40% will be conducted.

By-pass Pig Tests

By-pass pig tests will be conducted after the breaking force tests. Different wax thicknesses and oil contents will be investigated using by-pass pigs. The by-pass pigs will have 2% of the total cross sectional area open to flow.

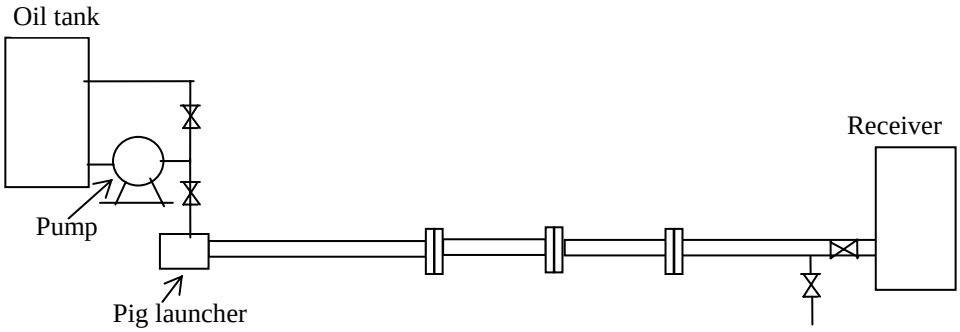

Figure 1—Schematic of Pigging Facility

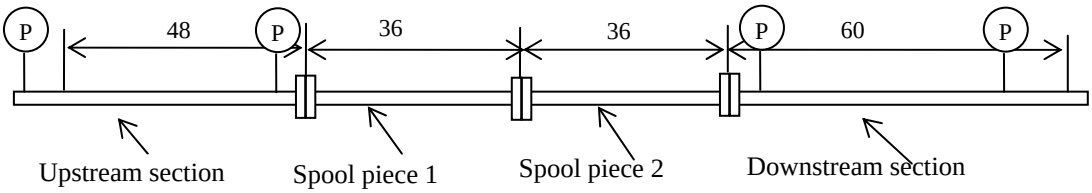

Figure 2—Test Section

Calendar of Events

2006

March 14-15	Technologies for Thermal Heavy Oil and Bitumen Recovery and Production—ATW, Calgary, Canada
March 28	TUHFP JIP Advisory Board Meeting, University of Tulsa Campus, President's Lounge, Allen Chapman Activity Center, Tulsa, Oklahoma
March 29	TUPDP Advisory Board Meeting, University of Tulsa Campus, Gallery, Allen Chapman Activity Center, Tulsa, Oklahoma
March 30	TUFFP Advisory Board Meeting, University of Tulsa Campus, Gallery, Allen Chapman Activity Center, Tulsa, Oklahoma
April 22-26	SPE/DOE Symposium on Improved Oil Recovery, Tulsa, Oklahoma
May 1-4	Offshore Technology Conference, Houston, Texas
September 19	TUHFP JIP Advisory Board Meeting, University of Tulsa Campus, Room to be Determined, Tulsa, Oklahoma
September 20	TUPDP Advisory Board Meeting, University of Tulsa Campus, Allen Chapman Activity Center, Tulsa, Oklahoma
September 21	TUFFP Advisory Board Meeting, University of Tulsa Campus, Allen Chapman Activity Center, Tulsa, Oklahoma
September 24-27	SPE Annual Technical Conference and Exhibition, San Antonio, Texas
TBA	The Heavy Oil Challenge: Recognition, Evaluation and Mobilization—Forum, Portugal
TBA	Who Owns the Deepwater Riser and Who Solves its Production Problems? - Forum, Portugal
October 3-6	SPE Russian Oil and Gas Technical Conference and Exhibition, Moscow, Russia
November 5-8	Deepwater Technology—ATW, Bangkok or Phuket, Thailand
November 5-8	Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, UAE

2007

February 28-March 2	International Symposium on Oilfield Chemistry, Houston, Texas
March 12-15	Middle East Oil and Gas Show and Conference, Bahrain
March 31-April 3	Production Operations Symposium, Oklahoma City, Oklahoma
April 15-18	Latin American and Caribbean Petroleum Engineering Conference, Buenos Aires, Argentina
April 30-May 3	Offshore Technology Conference, Houston, Texas
September 4-7	Offshore Europe, Aberdeen, Scotland
November 10-14	SPE Annual Technical Conference and Exhibition, Anaheim, California

Upcoming ABM's

March 28, 2006

Hydrate JIP Advisory Board Meeting
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
8:00 a.m. - 2:45 p.m.

TUHFP/TUPDP/TUFFP Facilities Tour
The University of Tulsa North Campus
2450 East Marshall
Tulsa, Oklahoma
3:00 - 5:00 p.m.

TUHFP/TUPDP/TUFFP Barbeque
The University of Tulsa North Campus
2450 East Marshall
Tulsa, Oklahoma
5:00 - 7:00 p.m.

March 29, 2006

TUPDP Advisory Board Meeting
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
8:00 a.m. - 5:00 p.m.

TUFFP/TUPDP Reception
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
6:00 - 9:00 p.m.

March 30, 2006

TUFFP Advisory Board Meeting
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
8:00 a.m. - 5:00 p.m.

September 19, 2006

Hydrate JIP Advisory Board Meeting
Location to be determined
Tulsa, Oklahoma
8:00 a.m. - 2:45 p.m.

TUHFP/TUPDP/TUFFP Facilities Tour
The University of Tulsa North Campus
2450 East Marshall
Tulsa, Oklahoma
3:00 - 5:00 p.m.

TUHFP/TUPDP/TUFFP Barbeque
The University of Tulsa North Campus
2450 East Marshall
Tulsa, Oklahoma
5:00 - 7:00 p.m.

September 20, 2006

TUPDP Advisory Board Meeting
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
8:00 a.m. - 5:00 p.m.

TUFFP/TUPDP Reception
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
6:00 - 9:00 p.m.

September 21, 2006

TUFFP Advisory Board Meeting
The University of Tulsa
Allen Chapman Activity Center
Tulsa, Oklahoma
8:00 a.m. - 5:00 p.m.