

This column provides examples of cases in which students have gained knowledge, insight, and experience in the practice of chemical engineering while in an industrial setting. Summer interns and coop assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of analytical tools used and the skills developed during the project should be emphasized. These examples should stimulate innovative approaches to bring real world tools and experiences back to campus for integration into the curriculum. Please submit manuscripts to Professor W. J. Koros, Chemical Engineering Department, University of Texas, Austin, Texas 78712.

## ACCELERATED BS/MASTER'S INDUSTRY PROGRAM IN CHEMICAL ENGINEERING

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The Accelerated BS/Master's Industry Program in Chemical Engineering was established at Texas A&M University in the fall of 1991. The program permits students with a GPA of 3.25 or higher to begin work toward the Master's degree, either Master of Science (MS) or Master of Engineering (ME), at the end of their Junior year and to complete the requirements for the degree in one additional year after receiving the BS degree.

A key feature of the program is an extensive research project (for the MS degree) or engineering project (for the ME degree) which is conducted in industry at the company site. The project is normally done during two summer periods, before and after the Senior year, but can also be done in two consecutive semesters.

During their Senior year, the students can take up to three graduate-level courses and receive credit toward three required undergraduate electives as well as credit toward the Master's degree for these courses. Since graduate credit is also given for the summer project work, the student can

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complete approximately one-half of the requirements for the Master's degree by the time the BS degree is awarded. One additional academic year beyond the BS degree, including the second work period, is required to complete all requirements for the Master's degree, which could thus be obtained after a total of five years of college work. Although this schedule is the "norm," many students are out of phase with the regular four-year undergraduate curriculum (the average student takes closer to four and one-half years for the BS degree), but the program is sufficiently flexible to accommodate these students.

To date, fifteen students have enrolled in the program—five the first year, four the second year, and six the third year. Two of them have completed the program (one with an MS and the other with the ME). One student decided to take a permanent job before finishing the program and dropped out. A total of eleven different companies have participated in the program, and the feedback from all participating students and companies has been positive.

### HOW THE PROGRAM WORKS

A program coordinator solicits participation in the program from both students and companies. Brochures and information on the program are mailed to companies, with a follow-up phone call. Students with a GPA of 3.25 or higher at the beginning of their Junior year may apply by submitting a resumé to the program coordinator. Participating companies are asked to submit a brief description of a project or project area in which the students would participate, which

is given to the student applicants. Interviews are then arranged between the company representatives and the students, and the companies subsequently select the students they wish to work with.

Once a match between the student and company is made, the company project supervisor is identified and the project is defined in more detail. The student, with the help of the program coordinator, then selects a faculty advisor who has an interest in the project's technical area and is willing to work with the student. A meeting at the company location is arranged between the student, the company supervisor, the program coordinator, and the faculty advisor. The program requirements, project objectives and methods, report requirements, and scheduling are discussed and agreed upon at this meeting, which typically occurs during the spring of the student's Junior year.

The student is supervised jointly by the industry supervisor and the faculty advisor, who normally visits the student at the company site at least once during each summer work period. Periodic progress reports are required of the student, as well as a comprehensive report at the end of each summer period. The ME degree requires one or more extensive engineering reports, and the MS degree requires a research project and thesis. Both degrees require a final oral examination, and the student's industry supervisor participates as an adjunct member of the student's advisory committee. The nature of the project determines whether it is appropriate for the MS or ME degree, and it is the students' choice as to which they wish to pursue. In practice, there are usually more good students available than there are company projects, so supply and demand comes into play in this decision.

The first summer work period is usually devoted primarily to the "learning" phase of the project and its necessary preparatory work. Students working toward the MS degree concentrate entirely on the research project, which is done at the company research laboratory site—whereas the students working toward the ME degree may typically be working simultaneously on several projects. The students receive four hours of graduate credit (research for the MS or internship for the ME) for each of the two summer work periods, based on their project reports.

The MS research projects are typically long-range, so there is no urgency in completing them within a short time frame, and the two-summer period is normally adequate. From the company's perspective, the ME projects are sometimes of a more urgent nature, and in such cases it is usually possible to identify two shorter-duration projects which can each be completed in one summer. Excellent cooperation of the companies involved, along with the flexibility afforded by the two degrees, has made it easy to identify and complete projects which are not only quite appropriate for the program but also challenging.

During the Senior year the student may take up to three

graduate-level courses (instead of the three elective chemical engineering courses specified in the curriculum) and receive credit toward both the BS and Master's degree for these courses. The elective courses are to be taken from a prescribed list of chemical engineering electives, including topics such as polymer engineering, bioengineering, environmental engineering, high-tech materials engineering, process safety engineering, etc. Most of these courses have parallel graduate-level courses covering the same or similar subjects, and the students in the accelerated program may take the graduate-level course and qualify for credit by exam for the corresponding undergraduate course. The student therefore satisfies the requirements for the BS degree at the end of the regular (four-year) curriculum and must then formally apply and be accepted into the graduate program.

The second summer work period is completed following the Senior year, and the project reports are submitted. All reports are reviewed and approved by the company supervisor before being submitted to the faculty advisor for review, revision, and final acceptance. The remaining course requirements for the Master's degree can be completed during the following academic year. The MS degree requires a total of thirty-two hours, including eight hours for the research thesis. The research project is more extensive and comprehensive than the ME engineering report, but the ME degree requires thirty-six hours of graduate credits, including eight hours for the engineering project report.

About half of the required course credits for both degrees consists of a basic core of required graduate courses, with the remainder being tailored to the specific interests of the student. The thesis or engineering report can be completed during the final year, and the student must then pass a final oral exam by the graduate advisory committee (which includes the industry supervisor).

Occasionally a project will involve proprietary company information. When this is the case, the company determines what information can be divulged and the student and faculty advisor execute a nondisclosure agreement. It is understood at the outset, however, that the project must involve sufficient disclosable information to form the basis of an acceptable MS thesis or ME report. The results of the MS work are expected to be publishable, although the ME reports usually are not.

## **BENEFITS TO THE STUDENT**

The most obvious benefit to the student might seem to be the opportunity to obtain a Master's degree in the least possible time (a minimum of five years of college work). In reality, however, the most significant benefit is the opportunity to engage in a research or engineering project in the industrial setting. Since the projects are proposed by the companies, the topics are of direct and timely interest to them—they are definitely "real world" projects. Students

have much more responsibility and independence on the project than they would in a typical summer internship or co-op assignment, and they get much more involved in an in-depth technical project.

For their summer work, students are paid by the companies at a level commensurate with their ability and experience, which is higher than the rate for a typical internship position. The companies are also asked to provide a \$2500/year fellowship stipend for the student for two years, since Master's students do not normally receive departmental financial support. Although this fellowship is not a mandatory requirement of the program, the majority of the participating companies do provide it.

Another benefit of the program is that students have ample opportunity to "prove" themselves to the company sponsor, and they can reasonably be assured of an offer of permanent employment upon completing the program. The students tend to be very enthusiastic about their projects and are highly motivated and interested, which promotes high-quality work.

### BENEFITS TO THE COMPANY

In addition to the direct benefit of the work performed by the student, the company has an opportunity to engage some of the best chemical engineering students and to evaluate their performance on a significant project over an extended period of time. There is no permanent obligation on the part of either the company or the student during this period, but a permanent job offer is a natural consequence when a good match of interests is achieved. Another benefit is an opportunity for increased interaction between the participating companies and chemical engineering faculty which often leads to other forms of interaction, research collaboration, etc.

### EXAMPLE PROJECTS

Table 1 shows the companies that have participated in the program, along with a brief description of some of the projects conducted by the students—the table also demonstrates the wide variety of projects that have been involved in the program. Four of the companies are presently sponsoring their second student in the program. Two students have finished the program—one with the MS degree and one with the ME degree. The former presented the results of his project ("A Thermodynamic Model for Predicting Wax Deposition from Crude Oils") at the national AIChE spring meeting in Houston in 1993.<sup>[1]</sup>

Although each of the projects is unique and no one project is truly representative of them all since they cover such a wide range of topics, a brief summary of the study on wax deposition from crude oils will be given here as an illustration of a sample project. The project was done at Core Laboratories in Houston by Loganathan Narayanan under the joint direction of Dr. Kosta J. Leontaritis of Core Labs and Ron Darby of Texas A&M. Narayanan had already finished his course requirements before beginning his project, which was done during two consecutive semesters.

The motivation for the project is the fact that many crude oils contain heavy hydrocarbon fractions which precipitate as a wax phase at low temperatures, leading to the plugging of pipelines and various other problems in the field. The project objective was to develop a thermodynamic model for predicting the liquid-solid wax phase distribution, based on a refinement of a previous model (Scatchard-Hildebrand<sup>[2]</sup>). The Lee-Kessler correlation,<sup>[3]</sup> along with the modified BWR equation of state, was used to calculate solubility parameters and molar volumes, and the Gibbs free energy equation was based on polymer solution theory, including a size exclusion

**TABLE 1**  
Companies Participating in the Texas A&M Accelerated BS/Master's Program

<i>COMPANY</i>	<i>DEGREE</i>	<i>PROJECT</i>
Texaco Research • Port Arthur, TX	MS	Experimental evaluation of a biofiltration process for removing VOCs from remediation site off-gas streams.
The Dow Chemical Co. • Freeport, TX	ME	Evaluation of factors limiting the operating efficiency of a large steam jet thermocompressor.
Brown & Root Braun • Houston, TX	ME	Technical and economical feasibility study of plastic recycling processes.
OXYCHEM, Chocolate Bayou, TX	MS	Analysis of relationship between properties and processing conditions and blown film properties for HMW HDPE polymer blends.
Core Laboratories • Houston, TX	MS	Modeling of waxy crude oil phase behavior using polymer solution theory.
SAIC • Clear Lake, TX	ME	Optimization of procedures for Process Hazards Analysis and Process Safety Management reviews.
ALCOA • Pt. Comfort, TX	MS	Modification of the non-Newtonian properties of bauxite mud residue for maximum solids loading and minimum viscosity.
Texaco Inc./EPTD • Houston, TX	MS	Computer modeling of crude oil phase behavior and recovery by steam flooding.
FINA Technical Center • Deer Park, TX	MS	Experimental and theoretical modeling, initiator optimization, and scale-up for a free-radical polymerization reaction.
BASF • Freeport, TX	MS	Experimental evaluation of a fluidized bed process as a substitute for a fixed bed catalytic process.
Phibro Energy USA, Inc. • Houston, TX	ME	Computer optimization of a catalytic cracking refinery unit for variable feedstock and product properties.

term from the Flory-Huggins theory to account for the range of carbon numbers. A key element of the model is a binary interaction coefficient which is used as a tuning parameter to fit experimental data. The model can be used to perform flash calculations as well as to determine the onset temperature or pressure for wax crystallization. Onset temperatures, as well as the effect of temperature and pressure on component distribution, have been determined for various crude oils and compared with experimental observations.

The crude oil compositions were characterized by nine discrete "pseudocomponent" fractions, from  $C_1$  to  $C_{20+}$ . The Lee-Kessler mixing rules were applied to these components, and the binary interaction parameters were determined by a computer optimization routine in comparison with literature data from Hansen, *et al.*<sup>[4]</sup> The predicted wax deposition onset temperatures using this model were in excellent agreement with experimental measurements and were consider-

ably better than predictions of previous models, as shown in Figure 1. Equilibrium compositions of the liquid and solid phases at the onset temperature were predicted, as well as the wax solubility as a function of temperature and pressure, as shown in Figure 2. There are insufficient data available in the literature for confirming these predictions, however.

After finishing his MS degree, Narayanan remained with Core Labs and is presently continuing this study. He is in the process of acquiring additional laboratory data on waxy crude phase behavior which will be used to further evaluate and extend the computer model.

## SUMMARY

In summary, it is fair to say that this program has been extremely well received by both the participating companies and the students. It is continuing to expand, and provides an excellent opportunity for combining an advanced chemical

engineering education with practical industrial experience, in a manner which is of significant benefit to the student and the company alike.

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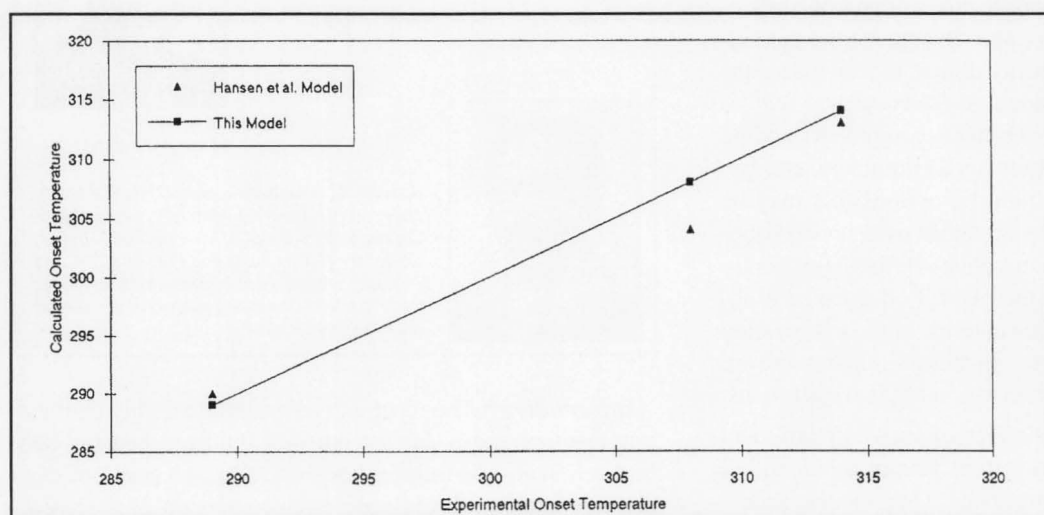


Figure 1. Comparison of experimental and calculated onset temperatures.

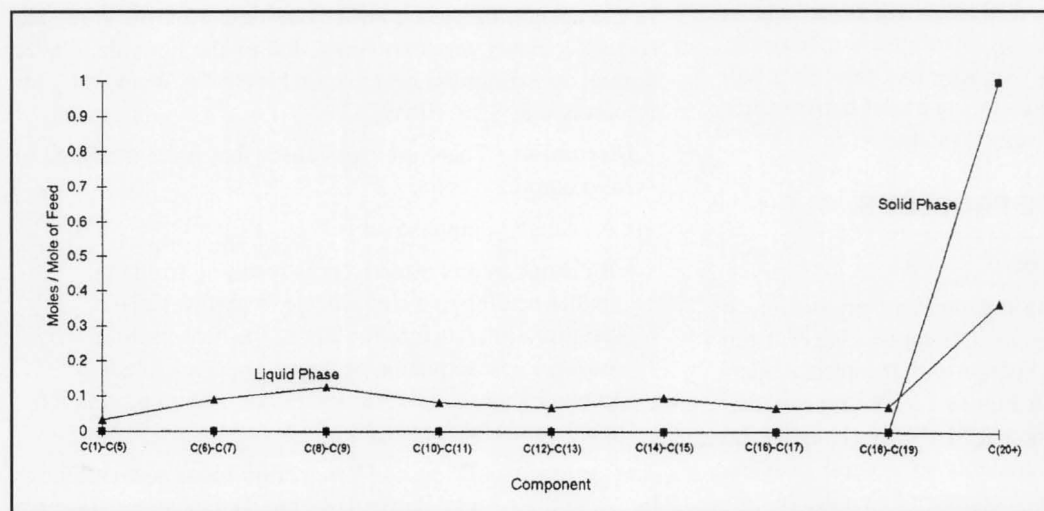


Figure 2. Equilibrium compositions of liquid and solid phases for mixture 1 at the onset conditions of 308 K and 1 atm.