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 internships and co-op assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of the 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, Georgia Institute of Technology, Atlanta, GA 30332-0100

UOP-CHULALONGKORN UNIVERSITY INDUSTRIAL-UNIVERSITY JOINT PROGRAM

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Since recovery of natural gas began in the Gulf of Thailand in the late 1970s, the need for petrochemical technology in that area has continually increased due to the rapid development of value-added processes for natural gas and LPG. Examples of such processes are dehydrogenation of ethane to ethylene and of propane to propylene. In addition to natural gas conversion, other areas of petroleum and petrochemical processing for converting petroleum to higher value-added products are of increasing interest in Thailand. One example is the conversion of naphtha to aromatics, followed by the separation of individual aromatics from each other. The individual pure aromatics can then be converted to even higher value products. For example, para-xylene can be converted to terephthalic acid, and subsequently to polyester.

Because of the high demand for petrochemical technology in Thailand, an international graduate program in "Petrochemical Technology and Polymer Science" was inaugurated in 1992 at Chulalongkorn University, one of Thailand's prominent universities. Through this international graduate program, select students who are enrolled in the Petroleum and Petrochemical College (PPC) at Chulalongkorn University have an opportunity to perform research for their thesis at one of three participating universities located in the United States. The participating U.S. universities and departments include the Department of Macromolecular Science and Engineering at Case Western Reserve University, the Department of Chemical Engineering at the University of Michigan, and the School of Chemical Engineering and Materials Science at the University of Oklahoma. When the Petroleum Technology Program was launched in 2002, the international graduate program was also extended to include an institute located in France, the Institut Francais du Petrole.

Through these international graduate programs, U.S. and French faculty members teach at PPC each year, and in addi-

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tion to teaching, some of the U.S. faculty members work with a Thai counterpart in supervising graduate students. Because they are jointly supervised by U.S. and Thai faculty members, some of the Thai students at Chulalongkorn University are given the opportunity to carry out part of their thesis work at one of the three U.S. universities.

After initial implementation of the international program, PPC recognized the importance of exposing its graduate students to practical experience. Thus, the international graduate program subsequently expanded its collaboration to an industrial setting. The UOP-PPC program is a first endeavor at providing Thai students with an opportunity to carry out research in an international industrial environment.

Exposure to industrial practices provides the students with a more comprehensive background than a solely academic-based education. The experience gained then acts as a model for scientists and engineers in the refining and petrochemical fields.

INDUSTRIAL INVOLVEMENT

The program was begun with the purpose of producing graduates of high international standards and developing world-class research and development (R&D) in the petroleum and petrochemical fields. As part of the program, industrial scientists are invited to give lectures and to supervise graduate students in their research at PPC.

In conjunction with this purpose, in 1997 Dr. Santi Kulprathipanja of UOP LLC, a graduate of Chulalongkorn University with over 25 years of industrial experience, was invited to give special experience- and industrial-application based lectures. In addition to his technical expertise, Dr. Kulprathipanja's knowledge of both the Thai and American cultures functions as a useful bridge by providing insight as to how to most effectively assist the students in adapting to their new environment.

UOP is a company known for process innovation, technology delivery, and catalyst/adsorbent supply to the petroleum refining, petrochemical, and gas processing industries. In 1998, Dr. Kulprathipanja supervised his first graduate student at PPC, and she later presented her research at a Canadian chemical engineering conference.

Observing that the program would be beneficial to Thai students, Dr. Kulprathipanja agreed to supervise two of them in 1999, allowing one to perform research at UOP for two weeks. From this beginning, future students supervised by Dr. Kulprathipanja were permitted to conduct basic research at UOP. Prior to returning to Thailand to complete their graduate work, the students are given an opportunity to present their research at a meeting of the American Institute of Chemical Engineers (AIChE), the American Chemical Society (ACS), or the North American Membrane Society (NAMS).

INVOLVEMENT/CONTRIBUTIONS OF UOP

The industrial aspect of the Petrochemical Technology and Polymer Science Program is currently supported by UOP. Housing expenses, along with a limited stipend for living expenses while the students are conducting experiments at UOP, are also provided by UOP each year. Travel expenses from Thailand to the United States are paid by the students while expenses incurred by attendance at the technical conference are provided by the university. UOP's participation caters to the mutual interests of the company and the students.

Through the program, UOP has an opportunity to help contribute to the establishment of petroleum and petrochemical R&D in Thailand by educating the students. The students learn industrial techniques while obtaining valuable research experience. With the guidance of other knowledgeable research scientists and technicians at UOP, the Thai students are exposed to proper experimentation procedures and safety guidelines, which are more stringent in the U.S. In return, through the students' research, UOP gains useful data and basic analytical information that it might otherwise not have the time or resources to explore.

CASE STUDIES

While at UOP, the students focused on four major research areas: adsorption, mixed matrix membranes, reactive separation, and catalysis. The following case studies will demonstrate the students' capabilities as they researched areas of adsorption and mixed matrix membranes at UOP LLC.

■ **Case 1 – Adsorption:** The Parex™ process, which uses UOP's well-known Sorbex™ "simulated moving bed" adsorptive separation technology to separate p-xylene from other C-8 aromatics, generates more than half of the p-xylene in the world. Because of UOP's expertise in C-8 aromatics adsorptive separation, three students were encouraged to carry out adsorption research in September and October of the years 2000 through 2002. The purpose of the adsorption study was to understand the interaction mechanism between the adsorbents and adsorbates. The adsorbents were zeolites X and Y exchanged with Li, Na, K, Rb, Mg, Ca, Sr, and Ba. The adsorbates were C-8 aromatics: p-xylene, m-xylene, o-xylene, and ethylbenzene. The adsorbents were characterized

using x-ray, TGA, ammonia-TPD, and chemical analysis. The students were initially trained to prepare adsorbents and C-8 aromatic feed stock. They subsequently studied the interaction using a myriad of techniques, including: the multicomponent dynamic pulse test to determine adsorbent selectivity to each C-8 aromatic, the multicomponent dynamic breakthrough to measure adsorbent selectivity, mass transfer rate and capacity for each C-8 aromatic, and single and multicomponent equilibrium adsorption isotherm to measure adsorbent selectivity and capacity for each C-8 aromatic. The results were then analyzed by a model simulation. In brief, the study indicated that the interaction mechanism between the adsorbents and C-8 aromatics is influenced by various factors, including: the acid-base interaction between zeolite and C-8 aromatics, exchanged cation size, C-8 aromatics feed composition, and zeolite Si/Al ratio. The results were used to fulfill the students' MS theses[1-3] and were presented at the AIChE meetings. UOP benefited from the results by gaining a basic understanding that will assist in further C-8 aromatics separation improvement development.

■ **Case 2 - Mixed Matrix Membranes:** There were two types of mixed matrix membranes (MMM) developed at UOP LLC in the early 1980s. The first MMM has zeolite embedded in the cellulose acetate (CA) polymer phase.[4,5] The second MMM is produced by casting an emulsion of polyethylene glycol (PEG) and silicone rubber (SIL) on a porous polysulfone (PS) support.[6-9] It was found that both types of MMMs offered many interesting features in enhancing selectivity and permeability if the MMM was composed of a comparable pair of polymer and zeolite or PEG. Based on this finding, four students were invited to the UOP Research Center during September and October of 1999 to 2002 to study/explore/discover new MMMs for interesting applications. Their objectives were to develop new types of MMMs for olefin/paraffin separation and carbon dioxide separation from natural gas. During the program, the students were trained to formulate MMMs, carry out permeation studies, and analyze data. Many encouraging MMMs were developed by the students for olefin/paraffin separation.[10-11] For example, the students found that ethylene/ethane and propylene/propane selectivity were enhanced by PEG/SIL/PS MMM.[10] Their selectivity was reversed with NaX/CA and AgX/CA MMMs, however.[11] In the case of carbon dioxide separation, a novel type of MMM was developed to enhance both CO_2/N_2 selectivity and CO_2 permeability. The MMM was composed of PEG, activated carbon, and silicone rubber on polysulfone .[12,13] Through this novel MMM, it was found that activated carbon can stabilize PEG and further enhance CO_2 permeability and selectivity. In addition to the basic understanding that UOP obtained from the students' work on activated carbon and PEG, UOP also filed a patent application due to the novel nature of the silicone rubber on polysulfone composite MMM. The data and analyses obtained from the research were used to fulfill the students' MS theses[10-13] and were presented at the AIChE meetings.

CONCLUSION

The Petrochemical Technology and Polymer Science Program stresses the reality that most graduate students will eventually work in industry. Exposure to industrial practices provides the students with a more comprehensive background than a solely academic-based education. The experience gained then acts as a model for scientists and engineers in the refining and petrochemical fields. In addition to the experience obtained by the students, UOP also benefited from the students' work. UOP has gained basic research information and has continued to use the information to further commercial process development. Overall, with the collaboration of UOP management, scientists, technicians, and others, the students in the program gained practical experience, presentation experience, and a more established reputation. The participating universities also benefited by gaining recognition on an international level.

The primary accomplishment of the program is to offer the opportunity for students in developing countries to obtain a solid foundation of knowledge by learning about other cultures and working in a professional environment. The following paragraphs demonstrate the impact the program has had on former participants.

TESTIMONIALS

By Ms. Warangkana Sukapintha and Mr. Thera Ngamkitidachkul* (1999) • Learning under real working conditions has broadened my vision and has enabled me to prepare for practical work. For two weeks, UOP allowed me to train in the R&D department, tour a UOP pilot plant, and visit the engineering and patent departments. These opportunities gave me the invaluable experience of seeing real work in a real company. I learned that one of the most important factors of doing work efficiently is being able to work well as part of a team. Additionally, as an unknown graduate student, it is almost impossible to be invited to an international meeting. Therefore, the opportunity to present a paper and attend the AIChE 2000 Spring National Meeting was one of the greatest experiences of my life. Now, in addition to the fundamental knowledge that I gained from my studies at PPC, I have also expanded my vision through industrial training. Overall, the opportunities to work under Dr. Kulprathipanja, to visit UOP, and to attend an AIChE meeting helped potential employers realize my capabilities.

By Mr. Varoon Varanyanond, Ms. Worrarat Rattanawong, and Ms. Passawadee Vijitjunya* (2000) • We obtained benefits from our stay at UOP that could not be obtained solely

**Thera Ngamkitidachkul, Passawadee Vijitjunya, Prueng Mahasaowapakkul, Kathavut Visedchaisri did not intern at UOP. They carried out their research work at PPC.*

from the University. The strongest advantage of working in a company was the availability of technical knowledge. Under the guidance of an expert, we acquired wider and deeper points-of-views. The state-of-the-art equipment and facilities also enabled us to effectively work on our research. We felt that anything was possible. The picture of how to apply the knowledge that we obtained from the classroom became clear. One of the most important educational tools we gained was the safety indoctrination provided by UOP. We also had the honor of presenting our work at an international conference where we developed communication skills and a result-focused style of thinking. These skills are some of our strongest points in getting a job. We believe the program will certainly give students a chance to develop themselves, as well as profit industry. Last, but not least, we would like to express our gratitude to Dr. Kulprathipanja, who worked so hard to give us this precious opportunity.

By Ms. Rattiya Suntornpun, Ms. Jutima Charoenphol, Mr. Visava Lertrodjanapanya, and Mr. Prueng Mahasaowapakkul® (2001) • For two months we were able to carry out our research at UOP under the close supervision of Dr. Kulprathipanja. This was a great opportunity for us to learn from a person with a strong industrial background. Meeting people from different backgrounds allowed us to learn more than just technical know-how. For example, they stimulated diverse ideas, increasing the likelihood that we would find the best solution to any problem. Moreover, we became more open-minded to other people's thoughts. We also learned that there were no exceptions when it came to safety matters. A large advantage of researching at UOP was the access to information. While we sometimes have to wait for a publication to be sent from abroad at PPC, this was never a problem at the UOP library. At the end of the program, our research was presented to an international audience at the AIChE 2001 Annual Meeting. We were able to practice our oral presentation skills and learn from the questions people asked about our research. Overall, this experience gave us more confidence in ourselves, making us more attractive to employers.

By Ms. Raweewan Klaewkla, Ms. Saowalak Kalapanulak, Ms. Parichart Santiworawut, Ms. Suwanna Limsamutchaiku, and Mr. Kathavut Visedchaisri® (2002) • We received a great opportunity from UOP to perform some of our research at UOP. We learned various techniques such as: preparing catalysts, casting membranes, setting up adsorption experimental lines, and using modern analysis instruments. An important observation that we made regarding UOP's working style was that while they directed most of their attention to their work, they were also prompt to provide each other with assistance. This general rule-of-practice influenced us to effectively work on our research. We were able to obtain both high quality and high quantity work in a limited amount of time. Before we left the United States, we also had a chance to present our research at the 2002 AIChE Annual Meeting. This trip opened our minds to the international world that we would not have been able to experience if we stayed only in our country and our college. Moreover, we learned a lot from the different cultures, languages, foods, living styles, and beautiful places. These impressive things could not have happened without Dr. Kulprathipanja and the UOP LLC staff. We would like to express our thanks and let them know that we are all very appreciative.

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