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, University of Texas, Austin, TX 78712.

PARTNERING WITH INDUSTRY
for a Meaningful Course Project

Rhonda Lee-Desautels
University of Kentucky at Paducah • Paducah, KY
Mary Beth Hudson
Wacker Specialties • Calvert City, KY
Ralph S. Young
Air Products and Chemicals, Inc. • Calvert City, KY

Engineering students can gain valuable benefits from an industry-sponsored project. Not only do students gain exposure to a full-scale chemical process, they also work closely with process engineers to collect and evaluate data. Students may even be allowed to collect data themselves by running product-testing equipment on-site. Once the data are analyzed, students can present their findings in a formal environment in front of industry personnel.

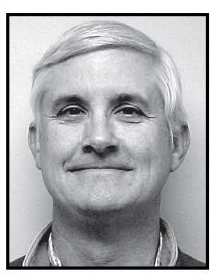
Many chemical engineering programs provide opportunities for students to tour regional industries, thus exposing them to the complexities of a full-scale chemical process. Rarely, however, are students given the chance to do coursework on a real problem with an actual state-of-the-art industry process. Yet such experience is especially valuable to students who do not receive a co-op or internship opportunity.

The University of Kentucky at Paducah has an advantageous location in close proximity to many industries. Calvert City, 17 miles east of Paducah, is home to 16 multinational industrial plants including Arkema Chemicals (formerly Atofina Chemicals), ISP Chemicals, Degussa Corporation, Celanese Chemicals, Westlake Vinyl Corporation, Wacker Polymer Systems, and Air Products and Chemicals. Many of these industries were involved in establishing the UK-Paducah engineering program, and now participate on an Industrial Advisory Board (IAB) that provides input into course content.

Through the IAB, contact was made with one member interested in collaborating on a course project. Wacker Polymer Systems, whose manufacturing site is on the Air Products plant site, provided the opportunity for an industry project applicable to Introduction to Particle Technology, a course offered biannually to upper-level undergraduates. Air Products is a minority partner in a joint venture with Wacker Polymer Systems on the operation of a spray-dryer system. The system manufactures a powder used in dry-mix mortars and other construction-related products.

***Rhonda Lee-Desautels** is an assistant professor of chemical and materials engineering at the University of Kentucky at Paducah. She received her Ph.D. in 1994 from The Ohio State University, under the direction of L.-S. Fan. Before taking a position in academia, she was employed by International Paper for seven years. Her research areas include particle-particle interactions, gas-solid fluidization, and advanced battery materials.*

***Mary Beth Hudson** is the site manager of Wacker Polymer Systems in Calvert City, Ky. She received a B.S. in chemical engineering from the University of Kentucky in 1989. She began her career as a process engineer for Air Products and Chemicals in 1989 and joined Wacker Polymer Systems in her present role in 1998.*



***Ralph Young** is the environmental manager at the Air Products and Chemicals plant in Calvert City, Ky. He received a B.S. in chemical engineering from Cornell University in 1971 and an M.B.A. from State University of New York (SUNY) at Buffalo in 1981. In 1991 he received a master's in environmental technology from Murray State University in Murray, Ky.*

Three projects were identified that: were of interest to Wacker; involved the spray-dryer system; and applied to the course content. One important project-selection criterion was that students would have the opportunity to perform particle-sizing analyses using the company's Beckman Coulter Counter laser diffraction analyzer. Therefore, each student would be involved in data collection on a real project, and would gain experience running a particle-sizing instrument.

This industry project, taking the place of the usual term paper assignment, counted as 20% of the final grade. The requirements of the industry project were: to tour the process site; obtain all available data from sponsors; collect additional data; compile and analyze the data; formulate conclusions and recommendations; write the report; and present to sponsors. One of the first steps was separating the 10 students enrolled in the course—all undergraduate seniors—into one of the three projects.

Figure 1. *The Wacker spray-dryer system in Calvert City, Ky.*

The industry projects were introduced during the fourth week of class, after students had been exposed to particle-size analysis, mixing and segregation of particles, and separation of particles from a gas—subjects related to the three chosen projects. Given a form containing a short description of the projects, the students were asked to rank their interest in each. All students were then assigned to their first or second project choice. One project group had four students and the other two groups each had three.

The industry tour of the spray-dryer process site (See Figure 1) took place during the fifth week of the course. The regular class meeting time was at 2 p.m. on Tuesdays/Thursdays for 75 minutes each. Arrangements were made to carpool on a Thursday to the Air Products plant site, leaving at the beginning of regular class time, and returning before 5 p.m. (one student had a 5 p.m. class). This three-hour time span allowed for 20 minutes travel to plant site, 30 minutes for introductions and a safety/orientation video, a one-hour plant tour, a 30-minute break-out session with engineers to discuss specific projects, and 20 minutes return travel. On the day of the tour, students were instructed to wear long pants, no open-toe shoes, and no sleeveless shirts. Our industry contacts provided flame-retardant smocks, hard hats, and safety glasses for the students at the plant site. After the tour, groups were responsible for making arrangements with a Wacker engineer for any experiments or analyses required by the projects.

THE INDUSTRY PROJECTS

Figure 2 shows a schematic of the Wacker spray-dryer process indicating the locations of the three projects.[1] In this process, the facility produces vinyl acetate-ethylene copolymer redispersible powders.[2] The conglomerated polymer powder that forms during the process is redispersed when contacted with water. These powders are used to improve

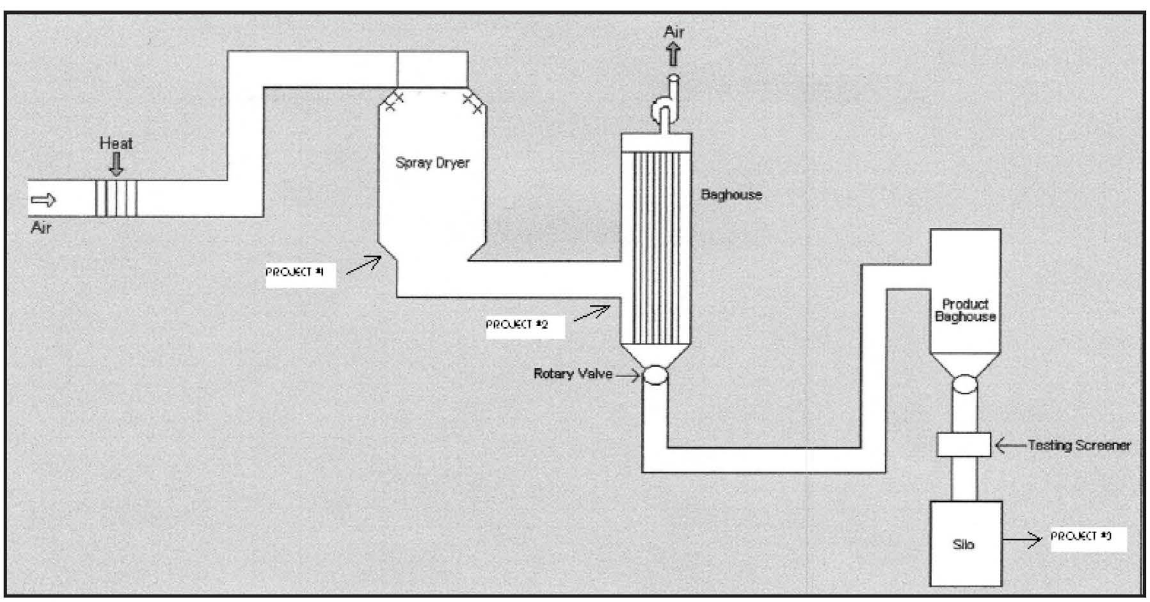


Figure 2. *Spray-dryer process flow diagram.*

adhesion, impact resistance, flexible strength, water and freeze-thaw resistance, and abrasion resistance properties of Portland cement and other architectural coatings. In the process, polyvinyl alcohol (PVOH) is mixed with emulsions and fed to the spray dryer.

High-pressure air and the solution are supplied to the top of the tower through spray nozzles. In the tower, water is driven from the mix leaving a dry powder at the bottom of the tower. The dried powder is pneumatically transported from the spray dryer to the main baghouse, where particles are separated from the gas before being transported to the product baghouse; there particles are screened and then stored in a silo. From the silo, the product powder is packaged and warehoused until delivery to the end user.

***Project 1.* Nozzle Configuration versus Particle-Size Distribution (PSD) of Spray Dryer Product**

In the spray-dryer tower, polymer is supplied to the top of the tower through a high-pressure ring of spray nozzles. The high pressure forces the liquid droplets through a small orifice, causing them to atomize into a fine spray. The first project investigates the effect of the nozzle configuration—that is, the sequence of nozzles that are operational—to the final PSD of the product. Students measured the PSDs based on three different spray-nozzle configurations using the Beckman Coulter Counter (See Figure 3). Students compared the PSDs and analyzed the results based upon differences in trajectories between the various configurations.

Figure 3. *Student Melissa Barrett and Professor Lee-Desautels use the Beckman Coulter Counter at the plant.*

The students found little variation between sample distributions for the three nozzle configurations. Wacker provided an airflow model of the spray dryer to aid the students in their analysis.[3] The airflow model showed a vortex forming in the tower, causing much turbulence. The students attributed the small variation in PSDs to the presence of this highly turbulent vortex region, which formed in the tower independently of nozzle configuration. The students connected the project to their coursework by proposing the various forms of agglomeration that can occur throughout the tower (See Figure 4) with capillary (c) and droplet (d) occurring at the top of the tower, nearer to the atomized liquid spray, and pendular (a) and funicular (b) agglomeration dominating toward the bottom of the column, where much of the liquid has evaporated.[4] This student group recommended a study to maximize polymer feed to the tower without causing excessive agglomeration by controlling nozzle configuration, nozzle pressure, and airflow.

***Project 2.* Baghouse Segregation Analysis**

Once the polymer powder has exited the spray tower, it has an average diameter of about 100 microns. It is mixed with clay particles (average size 60 microns) and pneumatically transported down flexible ductwork to the main baghouse. The main baghouse serves to separate the transport gas from the powder while controlling particulate emissions. The pneumatic ductwork splits into six separate ducts (labeled A, B, C, D, E, and F as shown in Figure 5) before entering the main baghouse.

The second project involved analyzing the uniformity of particle loading on the main baghouse after the splitting of the ductwork. Samples were collected by industry personnel at each of the six separate ducts leading into the baghouse. The students analyzed the samples with the Beckman Coulter Counter and compared distributions. The students found that the mean particle size differed widely among the ducts. Duct A contained the largest particles at a median size of 159 microns; Duct B particles had a median size of 76 microns; Ducts E and F averaged 60 microns; and Ducts C and D averaged

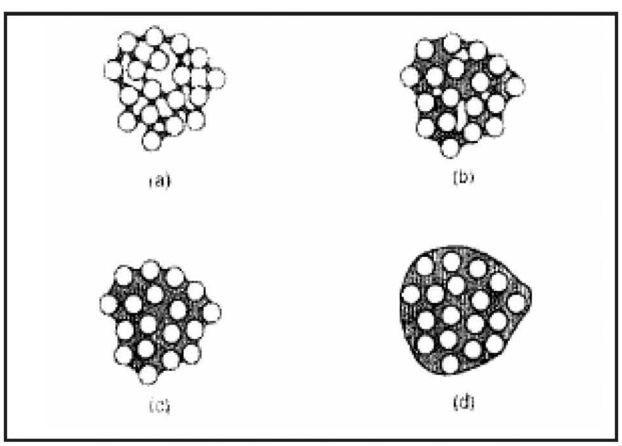


Figure 4. *Types of agglomeration occurring throughout the spray dryer.*

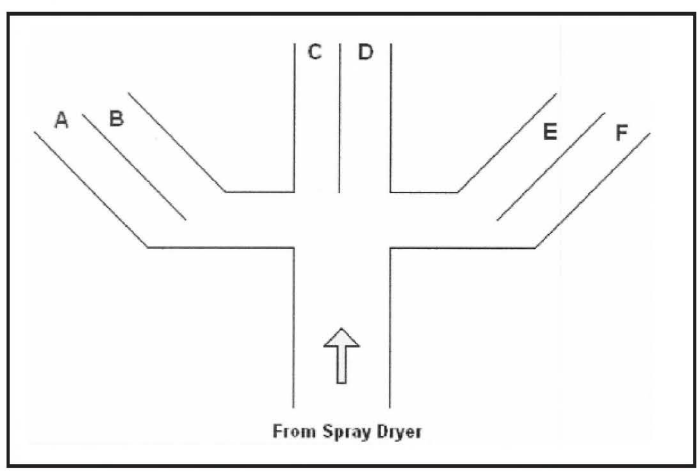


Figure 5. *Pneumatic ductwork to main baghouse.*

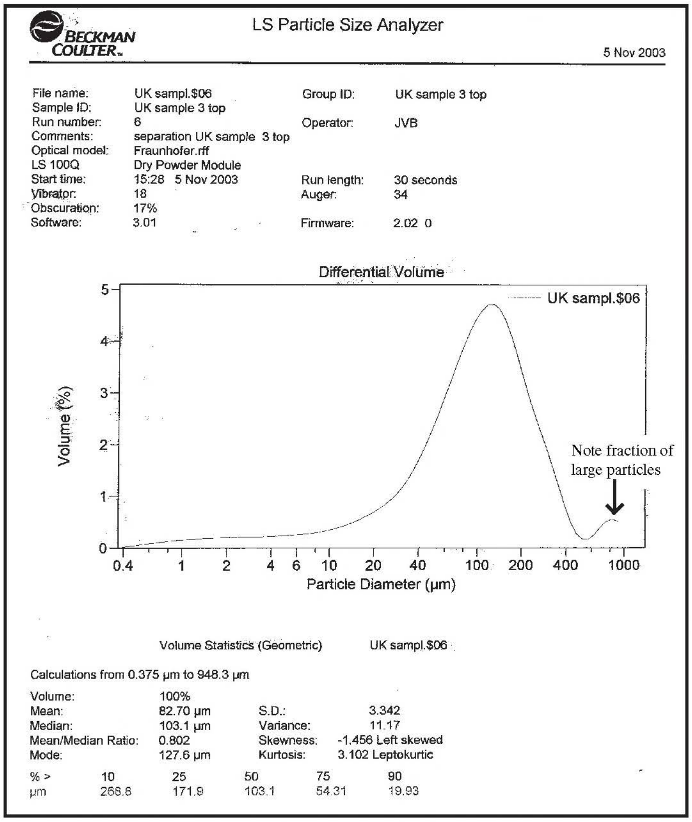


Figure 6. *PSD of particles sampled from top of container.*

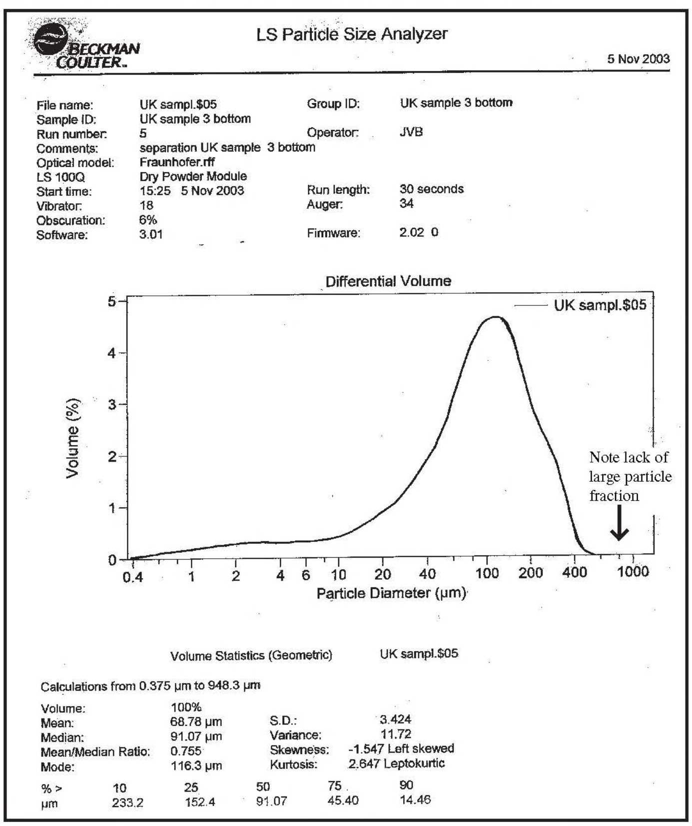


Figure 7. *PSD of particles sampled from bottom of container.*

45 microns. The students realized they couldn't explain these results in terms of inertial considerations alone, as the larger particles would be more likely to settle out when making the turn to Ducts A, B, E, and F—an effect that would lead to smaller particles in those ducts. The students decided they needed to gather more information about the ducting. On speaking with plant personnel, they were made aware that the lines had never been cleaned. The students also learned that directional plates had been installed in the transport lines to direct powder flow, but were nonfunctional due to buildup of wet product—essentially "gluing" them in place. Students proposed in their analysis that blockage due to material buildup was occurring in the pneumatic lines, and proposed it was concentrated around Ducts C and D, creating a region of restricted flow and high pressure drop. This restriction to flow in turn resulted in the smaller average particle sizes in these ducts, they theorized.

In addition to regular sampling of the transport lines to monitor particle distributions, the students recommended the directional plates in the ductwork be made operational to control powder fed to each duct. To prevent recurring problems, students proposed that since the majority of this buildup occurred during start-up of the process, developing stricter process start-up guidelines was recommended.

Project 3. Product Segregation During Transport

Once the powder has been sent through both sets of baghouses, it is transported to a silo where it is bagged and transported to consumers by truck. The third project investigated the segregation of powder product during the transport process. Some additional PVOH powder is added to the spray dryer product before reaching the product baghouse, and the company suspected some segregation might be occurring with handling and transport due to the PVOH having a smaller average particle size than the product. Having learned about the mechanisms of particle segregation,[4] students decided the mechanism of percolation was responsible due to the rise of coarse particles with agitation.

To test if segregation could occur, the students used a Ro-Tap device to agitate a sample container for a given amount of time to simulate the transport process. The students then took samples from the top and bottom of the shaken sample container and measured PSDs in the Beckman Coulter. The students also had an unshaken control sample that was measured. They found that the control had little difference in particle-size distributions between the top and bottom samples, with mean sizes of 95 and 96 microns, respectively. The shaken samples showed a greater percentage of large particles in the top samples than in the bottom samples, indicating the percolation and coarse particle-rise phenomena. In one shaken sample, after shaking for 30 seconds particles removed from the top of the container had a mean size of 83 microns, while particles from the bottom had a mean size of 69 microns (See Figures 6 and 7).

> ***"One of the most valuable aspects of this assignment from an industry perspective was the 'Presentation to Plant Technical Professionals.' Many entry-level engineers do not have the communication skills to clearly share their ideas with technical management. In many cases, engineering supervisors spend significant amounts of time working with entry-level engineers on their presentation and communication skills."***
>
> **—Industry feedback**

The students concluded that particle segregation is a negative effect for a product intended to meet certain requirements and specifications for its end use. Because this product had received no complaints, however, the students recommended no changes to the transportation of these powders. In spite of this concession, they further recommended making customers aware that this phenomenon occurs as a courtesy in case end users might want to homogenize the powder post-transport.

PROJECT PRESENTATIONS

At the end of the semester, each team presented its project findings to industry personnel at a seminar held in the Air Products Engineering Building conference room. Attending the proceedings were the three industry participants plus an additional invited engineer.

All students were required to participate in the presentation, and were given an outline on the required presentation format:

- ▲ *Background (Define the System and the Problem)*
- ▲ *Experimental (What You Did to Collect Data)*
- ▲ *Results/Analysis (Present the Data and Analysis)*
- ▲ *Discussion (Your Interpretation of the Results)*
- ▲ *Conclusions*
- ▲ *Recommendations*

The students in each group took turns presenting portions of the findings and were graded on the quality of the visual aides and delivery. The conference room was equipped with state-of-the-art audiovisual equipment including a projector and screen. The students were told to bring their presentations on a CD, with additional copies to hand out to industry attendees. Most students had never presented in this kind of corporate environment.

INDUSTRY PERSPECTIVE

In an effort to capture the industry viewpoint on the project experience, industry participants were asked to submit comments on the project. Their comments are summarized below. The comments are valuable, not only for students, but also for faculty to gain insight into what qualities industry values from their engineering employees. From the responses, it is obvious that the industry participants looked at the project more as a way to prepare students for the workforce, offering words of advice and critique, than a means of obtaining free labor. The industry participants had a genuine desire to provide a distinctive learning experience for our engineering students.

THE COMMENTS

Concerning the Performance of the Students

- ▲ *"From an industry perspective, I found the students enthusiastic and ready to do a 'hands-on' project. I'm not sure if everyone was trying to build their resume, but each student approached the project with an open mind and was prepared to learn something new. They quickly learned how to operate the test equipment and collect useful data."*
- ▲ *"In most cases, once the 'newness' of running the Coulter Counter and other test equipment wore off, the tedium of repetitive testing and analysis was apparent. In this respect each student was exposed to real industrial experience: 10-25% new and exciting opportunities versus 75-90% less exciting work. Every student has their own threshold of tedious, repetitive work. These types of assignments provide the opportunity to help students decide career paths such as process engineering in a plant environment or research assignments in lab environments."*
- ▲ *"In this project, it was obvious each student had some prior presentation*

training and experience. Many engineering curricula include this training in their degree requirements. Project leaders divided the presentation so that it flowed logically and used graphics to help the audience understand the project and results."

- ▲ *"The only element that was lacking in these presentations was the business case that would make or break a decision to allocate more resources. Since this aspect was not expected from the students, the technical staff was able to question the students and guide their thinking during the presentations. When the business case was made for a project—such as to increase plant production yields or benefit customers—many light bulbs seemed to go on in students' minds about the importance of the work. The interaction between students and industrial professionals was invaluable and one of the most important aspects of these projects."*

Concerning What is Valued in an Employee

- ▲ *"One of the most valuable aspects of this assignment from an industry perspective was the 'Presentation to Plant Technical Professionals.' Many entry-level engineers do not have the communication skills to clearly share their ideas with technical management. In many cases, engineering supervisors spend significant amounts of time working with entry-level engineers on their presentation and communication skills."*
- ▲ *"Most new engineers get bogged down in project details and sophisticated analysis, and cannot summarize pros and cons to drive a management decision."*
- ▲ *"Key qualities I value in employees are: problem solving ability, creativity, communication, teamwork, ability to accomplish goals with minimal direction, initiative, dependability, time-management skills, and the ability to successfully manage multiple constraints. The students' analytical ability is proven by their successful completion of the engineering curriculum. This project allowed them to demonstrate the other key qualities above as well."*
- ▲ *"Among the biggest constraints in industry are time and personnel. We are expected to accomplish more with less. Therefore, we need goal-oriented employees who can drive projects to completion. I have seen many engineers spend too much time evaluating options in trying to find the 'best' solution, only to create more problems by not achieving anything. I was told as a young engineer that you will be seen as more successful if you attempt to solve a problem five times over a year and only succeed on the fifth try than if you spend the whole year developing the perfect solution for the first try."*
- ▲ *"We do not have clearly defined problems with one correct answer in our work environment. Often, data to analyze the problem are missing or incomplete. Resources such as money, personnel, and time are limited. Engineers are challenged to determine the best solution to the problem based on the information and resources at hand. There is always an economic impact that has to be evaluated."*

Concerning the Benefit to Industry

- ▲ *"The results from the three projects reinforced our knowledge and confidence in what was happening."*
- ▲ *"The data will be useful to support the allocation of resources to cleaning the ducting to the main baghouse, alleviate any concerns with nozzle configuration influencing final product quality, and increase awareness of product segregation with transport."*
- ▲ *"The particle-size data collected in these projects have been used to address customer issues associated with particle size. Examples are a recent modification to a powder grade to decrease particle size/increase bulk density in response to a bulk handling issue with one of our largest customers, and a recommendation of powder grades to address an application which will require a coarser particle size."*
- ▲ *"One of the main benefits to industry in participating in these programs is that we get a better introduction to the students who will be entering the job market."*

STUDENT EVALUATIONS

The students were asked to evaluate the industry project in the optional-items section of the evaluation form. Four queries were made on the project. Students were also asked to provide personal comments specifically about the industry project. Eight of the 10 students taking the course were present for the evaluation.

- ▲ **Query 1. Rate your overall perception of the industry project.**
  Response: One rated it outstanding, four rated it good, two rated it average, and one rated it poor.
- ▲ **Query 2. The industry project has allowed me to learn more about a specific area of particle technology.**
  Response: One rated it outstanding, four rated it good, two rated it average, and one rated it poor.
- ▲ **Query 3. The industry project has helped me feel better prepared to seek employment with a company that manufactures/uses particles.**
  Response: Two rated it outstanding, three rated it good, two rated it average, one rated it poor.
- ▲ **Query 4. The industry project was a valuable component of the course.**

  Response: One rated it outstanding, four rated it good, and three rated it as poor.

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Partnering With Industry
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Instructor comment: I suspect the three students who rated this query as poor may have been reflecting on how valuable they felt their work was to Wacker and Air Products. This perception is expressed in the student comment #3 below.

Three students provided personal comments of the industry project on the evaluation form:

▲ ***Comment #1:*** *"I think the project would have gone better if we were able to run the equipment and take the samples ourselves."*

▲ ***Comment #2:*** *"It would be beneficial to our understanding of particle technology if we were allowed a more hands-on approach rather than analyzing given data."*

Instructor comment: I believe these two students were referring to collecting samples from the process, as all students were required to run the Beckman Coulter Counter.

▲ ***Comment #3:*** *"I thought it was neat to see an actual application of particles, but I didn't feel we actually accomplished anything."*

Comments from Industry Participants on evaluation results:

▲ *"I thought the feedback from the students was interesting and very candid. The students that rated the exercise as fair to poor shouldn't be viewed negatively, but rather that their engineering interests might lie in marketing, sales, or areas other than manufacturing."*

▲ *"Many students saw this project as a research study or 'make-work' study with no commercial application or contribution to a company's profit. When we started to connect the dots to commercial applications during the presentations and relate to benefits for the company, many students felt better about the project and started to appreciate their contributions."*

CONCLUSIONS AND RECOMMENDATIONS

It is obvious from the feedback that certain students were frustrated with the amount of contact they had with the process, and didn't perceive any benefit to the company from the projects.

Benefits weren't discussed until the end of the projects, in the presentation phase, which, in retrospect, was too late. In the future, it would be better to introduce benefits earlier in the execution of the projects. This might be best accomplished by having the industry personnel visit the classroom and introduce projects themselves, including potential benefits for the company. The students, however, should also be made to realize that these projects are chosen partially for the benefit of the industry, but the main driving force is to provide the students with a real-world learning experience.

"It would be beneficial to our understanding of particle technology if we were allowed a more hands-on approach rather than analyzing given data."
— Student feedback

Two of the biggest challenges of this exercise were: (1) finding industry projects that could feasibly be completed by the students in the project time frame, and (2) finding three projects requiring a comparable quality of student experience. As is obvious from these three projects, one resulted in a better student experience than others. In Project 3, the students had more project participation since they were able to plan and run experiments using the Ro-Tap machine, as well as run the particle analyzer. Projects 1 and 2, on the other hand, were straightforward as far as obtaining samples, which were collected by industry personnel, and the students' only participation in data collection was running the particle analyzer on the samples. In the future, this deficiency could be overcome by suggesting students shadow the industry participants during procedures that they can't perform themselves due to safety and liability issues. Also, more pre-planning by the instructor to assure better equity of the project experience may be necessary (initiation of partnership occurred in July, with the course beginning in August).

By the very nature of the projects being based on unanswered questions about the process, however, it would be impossible to predict project results and effects in this scenario.

Overall, the majority of the students felt the industry project was beneficial to their careers and experience. The project accomplished the main goals of (1) exposing students to a real-life particle manufacturing process, (2) gaining hands-on experience running a state-of-the-art particle measuring device, and (3) applying the basic concepts presented in the course.

ACKNOWLEDGMENT

We wish to acknowledge the support given by Josh Brien, Wacker engineer, in assisting students with data collection.

REFERENCES

1. State of Kentucky Title V Permit No. V-99-057 for Wacker Polymer Systems Spray Dryer Plant at Calvert City.
2. Wacker Polymer Systems, VINNAPAS: "Redispersible Powders and Dispersions Product Brochure," Nr. 5838-5838 (USA) 04 (2001)
3. Wacker Polymer Systems, *Air-Flow Model for Spray Dryer Process*, Burghausen, Germany (not formally published).
4. Rhodes, Martin, *Introduction to Particle Technology*, John Wiley and Sons, West Sussex, England (1998) ❐