INDUSTRIAL PERSPECTIVE ON TEACHING PARTICLE TECHNOLOGY

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Particle technology (PT) deals with such problems as powder flow, cohesion, adhesion, surface reactions, rheology, segregation, and fouling. Industry wants

- *Technical graduates who have some knowledge of PT*
- *Institutions to provide career-long training in PT*
- *External consulting and analytical resources*
- *Consortia to find answers for common design and operation problems*
- *Managers who recognize the importance of PT*

Three sectors must cooperate to accomplish this goal: industry, government, and academia. Academia provides most of the formal training, while government funds education in critical-but-undeveloped areas. Industry supports apprentice programs, external continuing-education courses, and research consortia such as the International Fine Particle Research Institute, the Solids Processing Services, the Engineering Research Center for Particle Technology (University of Florida), the Center for Advanced Materials Processing (Clarkson University), and the Particulate Materials Research Center (Pennsylvania State University).

How are the Nations that have Strong PT Positions Faring at this Point?

Japan's PT community is well organized and innovative, with an extensive industrial base and strong academic programs. For twenty-five years their APPIE organization has provided a strong informational base and a cohesive link between industry, university, and government. They support the East Asian professors of PT who hope to coordinate academic development of PT in Japan, China, Korea, Thailand, Singapore, and Taiwan.[1] The Hosakawa Corporation has acquired manufacturing plants in several countries, perhaps becoming the world's largest supplier of fine (dry) particle mills, mixers, classifiers, etc., and is a strong partner in academic research and consortia. Several observers, however, say that Japan's extensive support for research overseas may have caused research at home to suffer.[2-4]

In Germany, Rumpf's leadership in PT during the 1950s created a strong industrial and academic base.[5] Both German and U.S. chemical manufacturers recruit a large fraction of their PT experts from German and other European universities. But Freemantle[6] notes that economic pressures arising from reunification are causing some concern, that the number of PT centers and the duration of university training programs are under scrutiny, and that there has been a significant drop in engineering enrollment at major universities.

England, France, the Netherlands, and Switzerland have active academic centers and industrial centers of PT. A "Specially Promoted Program in PT" focused national attention on PT in England. For a decade it drew together academics from several disciplines to address complex problems. This program has been replaced by the equally successful "Soft Solids" program. The Netherlands has started similar efforts to coordinate research.[7] Australia, long aware of particle-related problems in the mining and minerals industries, has initiated a National Center for Multiphase Flow, funded through the Australian Research Council.

Russia has a long and strong tradition of technical excellence in PT, but Lepkowski[8] reports that since the breakup of the USSR the physical structure for technology has deteriorated and many faculty have become dependent on consulting income. Long-term industrial stability and the future of the relationship between government, industry, and academia remain questions without answers.

In contrast, the U.S. is now beginning to get its act to-

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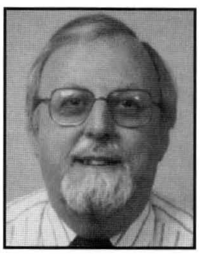

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gether, and the interaction between the Particle Technology Forum (PTF) of the American Institute of Chemical Engineering (AIChE), the Engineering Research Center for Particle Technology (ERC-PT) at the University of Florida (and other academic centers of PT), and a newly proposed development—the Particle Process Industries in the Americas (PPIA)[9]—should help us solve PT problems.

> ***. . . the challenge . . . for the next five years: . . . produce graduates who are both knowledgeable in PT and interested in entering management. . . . help convince present technology managers of the importance of PT in improving their operations. . . consider making the transition from academia to industry yourself . . .***

What is the Challenge?

Most of the products sold by chemical companies are in particulate form, but the technology for producing and handling particles in commercial processes is rarely taught in the United States. Consequently, although most of the production problems faced by new (or old) chemical technologists are related to particles, few of these technologists have had any formal training to help resolve them. The resulting cycle of guess-hope-fail-try again costs U.S. industries millions of dollars a year.[10] If U.S. universities do not help meet the challenge, those nations where technologists have superior training in this area will continue to expand their market share and to acquire U.S. companies, reducing taxes available for U.S. university support and relocating job opportunities to other nations.[11,12]

Alas, the vast majority of new engineering graduates in the U.S. have no idea of the technologies associated with processes involving particles, the commercial value of PT, what PT problems are easily solved, or what PT problems are difficult to solve and where to get help. In 1992, we listed several factors that make resolution of the challenge difficult:[13]

- *The necessary elements of expertise reside in many disciplines, no one of which provides a principal "home" for particle technology.*
- *Courses are being developed in isolation, and it is hard to add them to an existing curricula or to replace courses that are now in place.*
- *A multidisciplinary team effort is needed; but it is hard to construct or to reward such teams using current academic management and promotion policies.*
- *There was (in 1992) no national policy to develop or to support education in PT.*

All engineering fields feel they deserve more time in the curriculum, but there are limits on both faculty positions and money for new laboratories. Three- and four-year degree programs have very full curricula, so PT would have to displace something. This will probably not happen. Five-year diploma or MS programs probably have room for one course in PT fundamentals. While U.S. universities offer a few specialized MS and PhD degrees, graduates of such programs rarely have well-rounded backgrounds in PT because of the lack of PT courses.

Many disciplines are required to deal with PT problems:

▶ **Chemistry** • crystallization (morphology, defects), bulk and surface composition, surface reactivity and adsorption, surfactant synthesis, dispersion stabilization

▶ **Material Science** • hardness, modulus, crack propagation, strength, compressive behavior, ductility, plasticity

▶ **Chemical/Mining Engineering** • design and operation of economic processes to manufacture particles with the desired properties at high capacity, yield, and purity

▶ **Mechanical/Civil Engineering** • design, operation, and maintenance of hoppers, milling, conveying equipment

▶ **Physics** • design and use of measuring equipment, application of fields to modify solids behavior

▶ **Process Control Engineering** • design and implementation of process control from particle formation to packaging

▶ **Mathematics/Computer Science** • modeling of manufacturing processes and of particle interactions, simulation, visualization, and data handling

▶ **Information Science** • compilation of global literature into meaningful literature surveys, improved communications, and better transfer of information

▶ **Statistics** • development of efficient experimental programs, methods for data reduction and presentation

How Much has been Accomplished?

Much has happened since we posed the challenge to academia in 1992:[13]

1992	The Particle Technology Forum (PTF) was approved by the AIChE. It provided a focal point for interdisciplinary and intersocietal exchange of information.
1993-94	The National Science Foundation funded four PT training courses for university faculty, with the expectation that they would introduce PT material into their courses.
1994, 96	The PTF held successful meetings; the next will be in 1998.
1994	Publication of "The Legacy of Neglect in the U.S."[10]
1994	ERC-PT established at the University of Florida
1995	NSF funded the "Virtual Technology Market" concept. It is a Web site hosted by George Washington University (Washington, DC) at http://www.seas.gwu.edu/guest/vtm
1995	Publication of "Teach 'Em Particle Technology"[13]
1996, 97	Several new books, CD-ROMS, courses, modules, and Web sites (see below)

Who is Leading the Effort Now?

The PTF (http://www.eng.nsf.gov/ptf/) has formed a Task

Force on PT Education and has assigned working group leaders for

- Particle Formation from Gases
- Crystallization and Precipitation
- Size Enlargement and Agglomeration
- Comminution and Attrition
- Tribology, Friction, and Interparticle Forces
- Particle Characterization
- Fluidization and Multiphase Flow
- Solids Flow, Handling, and Processing
- Particle Mixing, Segregation, and Classification
- Powder Mechanics
- Particle Reaction Engineering
- Simulation, Modeling, and Visualization
- Dispersion, Rheology, and Solid/Liquid Separation
- Deposition, Fouling, Erosion, and Wear

The ERC-PT (http://www.erc.ufl.edu/) has had a significant impact on education related to PT for many age groups during its three-year existence:[15]

- Precollege Awareness - The University of Florida's Center for Precollegiate Education brings in over 300 junior and senior high students annually. One activity is a presentation by the ERC-PT.
- College Courses - There are now three new engin-eering courses in PT.
- Extension to Other Colleges - Four course modules in PT are available.
- Printed Resources - One textbook has been completed and several are in preparation.
- Undergraduate Research Projects - About 60 are funded each year.
- Graduate Research Assistantships - Over 30 are funded each year.
- Continuing Education - Three courses in 1996-97 had 150 industrial participants.

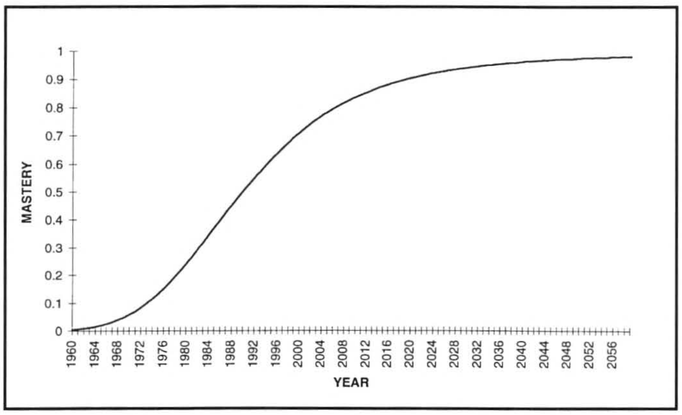

Figure 1. *Mastery of a technical area, with t_0=1950 and t_{CRIT}=1990*

New curricula are being developed in the schools listed below; the U.S. needs to launch many more like them in the next few years. New beginnings will provide new options.[16]

- City College of New York: Undergraduate and graduate laboratory experiments
- American Filtration Society: Short courses coordinated between four universities
- New Jersey Institute of Technology:[17] Undergraduate and graduate courses
- University of Pittsburgh: Coordinating virtual distance learning in PT for graduate programs at four universities
- Yale University: Courses in interfacial phenomena, colloids, and aerosols.
- University of Cincinnati: Courses in PT and particle processes

What Remains to be Done?

The PT community understands the stakes involved in having graduates trained in this field. We must generate a demand for such graduates in a way that can be understood by academia and government (and by industrial management).

- *Industry should specify in personnel ads that it wants engineers with awareness of PT basics.*
- *National technical societies should insist that education include PT examples.*
- *National technical societies must continue to provide specific sessions for the presentation of PT research papers.*
- *Authors should include PT topics in their chemical engineering texts.*
- *Faculty should provide PT examples in many courses and laboratories.*
- *Universities (several) should offer coherent graduate training programs in PT. These programs should include a period of industrial internship.*
- *Universities (several) should establish a multilevel structure for comprehensive continuing education in PT.*
- *Federal agencies should recognize the need to fund equipment and building facilities to support PT research programs.*

How Can You Decide What to Change?

University faculty should carefully consider the value of the elements in their courses according to where those elements fall on the S-curve of mastery as a function of time, $m = z^4/(1+z^4)$, where $z = (t-t_0)/(t_{CRIT}-t_0)$ (see Figure 1),

The Emerging Stage • In the early days (when $z < 5/8$), so little is known about the phenomenon that it can be mentioned in courses and textbooks only as an interesting and possibly useful phenomenon. We cannot teach what we do not understand. Industries may "bet" on success by investing research funds and personnel in the technology, but they recognize that their efforts may not result in commercialization. High temperature superconductors are an example of a technology in the emerging stage.

The Vital Stage • As the fundamental relationships become clearer ($5/8 < z < 8/5$), our understanding and ability to apply them to commercial activity is partial, but developing. Students trained in the area can make a significant impact on improving industrial operations. Industries may either keep secret or patent newly gained information. They can profit substantially from an advance that their competitors do not know or cannot practice due to patent constraints. Filtration is an example of a technology in the vital stage.

The Mature Stage • In the later years of mastery ($8/5 < z$), understanding is thorough, and excellent equipment and consultant assistance is widely available. It generally costs less to buy the technology than to practice it in-house, so college courses can simply summarize the material. People who want to specialize in the field will receive their advanced training from apprenticeship or courses taught in-house by the firms that specialize in that technology. Electric motors are an example of a technology in the mature stage.

We should admit that some technology elements currently occupying considerable space in the curriculum have moved from the vital to the mature stage and should be treated at less length, leaving room for the vital elements of PT. The goal of undergraduate engineering education should be to provide all students with an awareness of and a value for PT and with basic skills to build on. Graduate education should provide at least some experience with advanced PT concepts. At both levels, course and laboratory work should be supplemented with practical experience provided by summer work programs or internships.

Summary, a New Project, and a New Challenge

We have made good progress in the last five years. People at the highest levels of academia, government, and industry now recognize the value of PT. A number of programs in PT have been added to the few previously in existence, and the current programs have significant strength and momentum. The success of the current programs should attract others who wish to have similar success in helping graduates find employment.

It is now clear, however, that training faculty in PT and adding PT courses to the curriculum are not the answer for most universities. Instead, we shall have to rely on faculty who have a little background in PT to incorporate PT understanding and examples into their present courses. To facilitate this process, several participants at the Snowbird Conference agreed to develop a Web site through which multimedia educational modules contributed by experienced educators and reviewed by senior members of the PT community could be widely and inexpensively disseminated. A printed journal incorporating the modules will provide permanence, copyright protection, and concrete evidence of the significant professional contributions made by the authors. Since the meeting at Snowbird, the PTF has agreed to sponsor the project and to provide editors, and the ERC has agreed to host the Web site. There is now a demonstration site at http://erc.ufl.edu/erpt/.

National technical success will not come simply from funding national research programs and educational modules in PT. Research results are published quickly and benefit companies everywhere. Students who participate in nationally funded programs come to our universities from many nations and upon graduation are hired by companies from around the globe. Consequently, government funding will improve a nation's competitive situation only if that nation's industries make the earliest and best use of the research results and students. To do that they need savvy technology managers.

Here, then, is the challenge to educators for the next five years: You must produce graduates who are both knowledgeable in PT and interested in entering management. You must help convince present technology managers of the importance of PT in improving their operations. You might even consider making the transition from academia to industry yourself, where you can contribute directly to improving asset productivity for U.S. industry. In short, "Savvy technology *managers:* train 'em, convert 'em, or become one!"

REFERENCES

1. Matsumoto, K., "The First East Asia Professors' Meeting of Powder Technology," *1997 Adv. Powder Technol.,* **8,** 85 (1997)
2. Manifold, D.L., "Japanese Corporate Activities in Asia," *Chemtech,* p. 48, June (1997)
3. Nakanishi, K., "Scientific Research and Education in Japan," *Chem. and Eng. News,* p. 30, Dec. 2 (1991)
4. Tremblay, J-F., "Great Science in Hong Kong?" *Chem. and Engg. News,* p. 50, Aug. 18 (1997)
5. Davies, R., "Impact of Particle Processing Technology on U.S. Industry and Academia," H. Rumpf Memorial Colloquium, Karlsruhe, Germany, Nov. (1996)
6. Freemantle, M., "Turbulence Roils German Science," *Chem. and Eng. News,* p. 42, April 21 (1994)
7. Layman, P., "Shortage of Chemists Spurs Dutch Programs," *Chem. and Eng. News,* p. 28, Aug. 18 (1997)
8. Lepkowski, W., "U.S. Aid to Soviet Scientists Falters," *Chem. and Eng. News,* p. 30, April 7 (1997)
9. Davies, R., "Industry/University Interactions of PARSAT," IMECI '97, Dallas, TX (1997)
10. Ennis, B.J., J. Green, and R. Davies, "The Legacy of Neglect in the U.S.," *Chem. Eng. Prog.,* p. 32, April (1994)
11. Guschl, R.J., "Technology Transfer: Too Many Options?" *Chemtech,* p. 7, July (1997)
12. Rosenzweig, M., "Will Foreign Students Become an Endangered Species?" *Chem. Eng. Prog.,* p. 7, August (1997)
13. Nelson, R.D., R. Davies, and K.J. Jacob., "Teach 'Em Particle Technology," (summary of 1992 talk), *Chem. Eng. Ed.,* p. 12, Winter (1995)
14. Bungay, H., "Linking to the Real World," *Chemtech,* p. 9, June (1997)
15. Donnelly, A.E., and R. Rajagopalan, "Particle Science and Technology: Educational Initiatives," *Chem. Eng. Ed.,* **32,** *122 (1998)*
16. Wilkinson, S., "New Engineering College Incubates Education Reform," *Chem. and Eng. News,* p. 11, June 16 (1997)
17. Dave, R.N., I.S. Fischer, J. Luke, R. Pfeffer, and A.D. Rosato, "Particle Technology Concentration at NJIT: An NSF-CRCD Program," *Chem. Eng. Ed.,* **32,**102 (1998) ❐