What Chemical Engineers Do

Last May, chemical engineering seniors at UMD took their last final examination, attended their graduation ceremonies, flipped their tassels and threw their mortarboards in the air, enjoyed their farewell parties, said goodbye to one another and promised faithfully to stay in touch, then headed off in an impressive variety of geographical and career directions.

Are you thinking about following in the footsteps of those graduates — spending the next few years learning to be a chemical engineer and possibly the next 40 applying what you learn in a career? If so, it is a fairly safe bet that, like most people in your position, you have only a limited idea of what chemical engineering is or what chemical engineers do. A logical way for us to begin answering these questions might therefore be with a definition of chemical engineering.

Unfortunately, no universally accepted definition of chemical engineering exists, and almost every type of skilled work you can think of is done somewhere by people educated as chemical engineers. We will therefore abandon the idea of formulating a simple definition and instead take a closer look at what those recent graduates did, either immediately after graduation (or following a well-earned vacation).

Consider these examples and see if any of them sound like the sort of career you can see yourself pursuing and enjoying.

• About 45% of the class went to work for large chemical, petrochemical, pulp and paper, plastics and other materials, or textile manufacturing firms.

• Another 35% went to work for government agencies and design and consulting firms (many specializing in environmental regulation and pollution control) and for companies in emerging fields such as microelectronics and biotechnology.

• About 10% of the class went directly into graduate school in chemical engineering. The masters degree candidates will get advanced education in traditional chemical engineering areas (thermodynamics, chemical reactor analysis and design, fluid dynamics, mass and heat transfer, and chemical process design and control), and in about two years most of them will graduate and get jobs doing process or control systems design or product development. The doctoral degree candidates will get advanced education and work on major research projects, and in four to five years most will graduate and either go into industrial research and development or join a university faculty.

• The remaining 10% of the class went into graduate school in an area other than chemical engineering, such as medicine, law, and business — building on their chemical engineering problem solving skills.

• Several graduates went to work for companies manufacturing specialty chemicals — pharmaceuticals, paints and dyes, and cosmetics, among many other products. All of these companies used to hire only chemists to design and run their production processes, but in the past few decades they discovered that if they wanted to remain competitive they would have to pay

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attention to such things as mixing efficiency, heat transfer, automatic temperature and liquid level control, statistical quality control, and control of pollutant emissions. They also discovered that those are areas in which chemical engineers are educated and chemists are not, at which point these industries became an increasingly important job market for chemical engineers.

- Some went to work for companies that manufacture integrated semiconductor circuits. A critical step in the production of (for example) computer chips involves coating small silicon wafers with extremely thin and uniform layers of silicon-containing semiconducting materials. The technique used for this process is chemical vapor deposition, in which the coating material is formed in a gas-phase reaction and then deposited on the surface of the wafer. The graduates working in this area may be called on to identify reactions that can be used to produce the desired films, determine the best conditions at which to run the reactions, design the reactors, and continue to improve their operation.

- Some took elective courses in biochemistry and microbiology and got jobs with small but rapidly growing biotechnology firms. One graduate works on the design of pharmaceutical production processes that involve immobilized enzymes, biological chemicals that can make specific reactions go orders of magnitude faster than they would in the absence of the enzymes. Several others work on processes that involve genetic engineering, in which recombinant DNA is synthesized and used to produce valuable proteins and other medicinal and agricultural chemicals that would be hard to obtain by any other means.

- Some joined companies that manufacture polymers (plastics). One is working on the development of membranes for desalination of seawater (fresh water passes through, salt is kept out) and for gas separations (hydrogen passes through and hydrocarbons are kept out, or vice versa); another is developing membranes to be used in hollow-tube artificial kidneys (blood flows from the patient's body through thin-walled tubes; metabolic wastes in the blood pass through the tube walls but proteins and other important body chemicals remain in the blood, and the purified blood is returned to the body).

- A few of the graduates went to medical school. (Chemical engineering graduates who take several electives in the biological sciences have a strong record of success in gaining medical school admission.) One went to law school. Others enrolled in Master of Business Administration programs and after graduation will probably move into management tracks in chemical-related industries.

- One graduate joined the Peace Corps for a two-year stint in East Africa helping local communities develop sanitary waste disposal systems and also teaching science and English in a rural school. When she returns, she will complete a Ph.D. program, join a chemical engineering faculty, write a definitive book on environmental applications of chemical engineering principles, quickly rise through the ranks to become a full professor, resign after ten years to run for the United States Senate, win two terms, and eventually become head of a large and highly successful private foundation dedicated to improving education in economically deprived communities. She will attribute her career successes to the problem-solving skills she acquired in her undergraduate training in chemical engineering.

- At various points in their careers, some of the graduates will work in chemical or biochemical or biomedical or material science laboratories doing research and development or quality engineering, at computer terminals
designing processes and products and control systems, at field locations managing the construction and startup of manufacturing plants, on production floors supervising and troubleshooting and improving operations, on the road doing technical sales and service, in executive offices performing administrative functions, in government agencies responsible for environmental and occupational health and safety, in hospitals and clinics practicing medicine or biomedical engineering, in law offices specializing in chemical process-related patent work, and in classrooms teaching the next generation of chemical engineering students.

Even the chemical engineering graduates who go into a traditional chemical manufacturing process end up performing a wide variety of different tasks. Consider the following example, and see if any of the problems described seem to present the sort of challenge you can see yourself taking on and enjoying.

A chemist in your company’s research and development division has discovered that if he mixes two reactants in a certain proportion at an elevated temperature, he obtains a product significantly more valuable than both reactants. The company contemplates manufacturing the product using a process based on this reaction. At this point the matter becomes an engineering problem or, more precisely, hundreds of engineering problems.

A. What type of reactor should be used? A long pipe? A large tank? Several smaller tanks? An extremely large test tube? How large? Made of what? Does it have to be heated? If so, how much and how? With an electrical heater inside or outside the reactor? By passing a hot fluid through a heating coil in the reactor? By heating the reactants before they get into the reactor? Does the reaction supply its own heat, so that heating is needed only for startup? If so, can the reactor "run away" and possibly explode? Should control measures be introduced to prevent this? What kind?

2. Where should the reactants be obtained? Buy them, or make them? In what proportions should they be fed to the reactor?

3. Should the reactor effluent, which contains the product and unreacted reactants, be sold as is, or should the product be separated from the reactants and the latter be sent back to the reactor? If separation is desirable, how can it be accomplished? Heat the mixture and draw off and condense the vapor, which will be richer in the more volatile substances than the original mixture? Add another substance that extracts the product and is immiscible with the reactants, and then separate the two phases mechanically? If all of the process materials are gases at the reaction temperature, can the mixture be cooled to a temperature at which the product condenses but the reactants do not, or vice versa, or if they are liquids can the mixture be cooled to a temperature at which the product crystallizes? If one of these alternatives is chosen, what kind of equipment is needed? What size? What materials? What are the heating or cooling requirements? Are controls needed to keep the operation of the process within rigid limits? What kind of controls? Should they be manual or automatic?

4. How should the reactant and product streams be moved to and from the reactor and any heating, cooling, and separation equipment involved in the process? By gravity from a raised feed tank? With pumps, or blowers, or compressors, or conveyor belts? What kinds? How big? In pipes made of what?

5. Is enough known about the reaction system to be able to answer all of these questions, or should additional laboratory studies be carried out? What studies? Can
the laboratory data be used directly to design the industrial plant, or should a smaller pilot plant be constructed first to test the design? How much smaller?

6. Are waste products produced by the process? In what quantities? Are they potentially harmful if released untreated into the environment? If so, in what way? What should be done to reduce pollution hazards? Chemically treat the wastes? Dump liquid and solid wastes into containers, seal and cart them out to sea? Disperse gases in the atmosphere with a high stack? Precipitate solids electrostatically from gas exhausts?

7. How much of the process should be automated, and how should the automation be done?

8. How much will all of this cost? For how much can the product be sold, and to whom? How much money will the process net each year? Is it enough to make it worthwhile? If so, where should the plant be built?

9. Once the plant has been built, what procedure should be followed for startup?

10. Six months later when startup has been achieved, why is the product not coming out the way it did in the laboratory? Is it an equipment malfunction or a change in conditions somewhere between the laboratory and industrial process? How can we find out?

What can be done to correct the problem? Is it necessary to shut down the operation for modifications?

11. Is it significant or just a coincidental series of bad breaks that there have been three explosions and four fires within six months in the reactor unit? In either case, how do we stop them from recurring?

12. When the process finally starts working perfectly and the next day an order comes down to change the product specifications, how can it be done without redesigning the entire process? Why didn’t they think of this before they built the plant?

The different careers and tasks described here are clearly too diverse to fall into a single category. They involve disciplines including physics, chemistry, biology, environmental science, medicine, applied mathematics, statistics, computer science, economics, management and information science, research, design, construction, sales and service, production supervision, and business administration.

The single feature they have in common is that chemical engineers can be found doing them.

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