Enterprises of Chemistry

A History of the International Chemical Industry. FRED AFTALION. University of Pennsylvania Press, Philadelphia, 1991. xxiv, 411 pp., illus. $39.95; paper, $14.95. The Chemical Sciences in Society Series. Translated from the French edition by Otto Theodor Benfey.

Few human activities can equal in diversity and impact the study of how materials behave and of how they can be manipulated to suit the needs of everyday life. Moreover, significant progress in such manipulations has in recent centuries been made possible only when the understanding of how to make better materials has been carried over into large-scale operations. By the end of the 18th century, chemists had developed methodologies for learning about the properties of both elements and materials and were called upon to undertake improvements in many industries. Subsequently, the discipline of chemistry grew hand in hand with its application, and the main problems tackled by chemists until the end of the 19th century were invariably related to industrial processes.

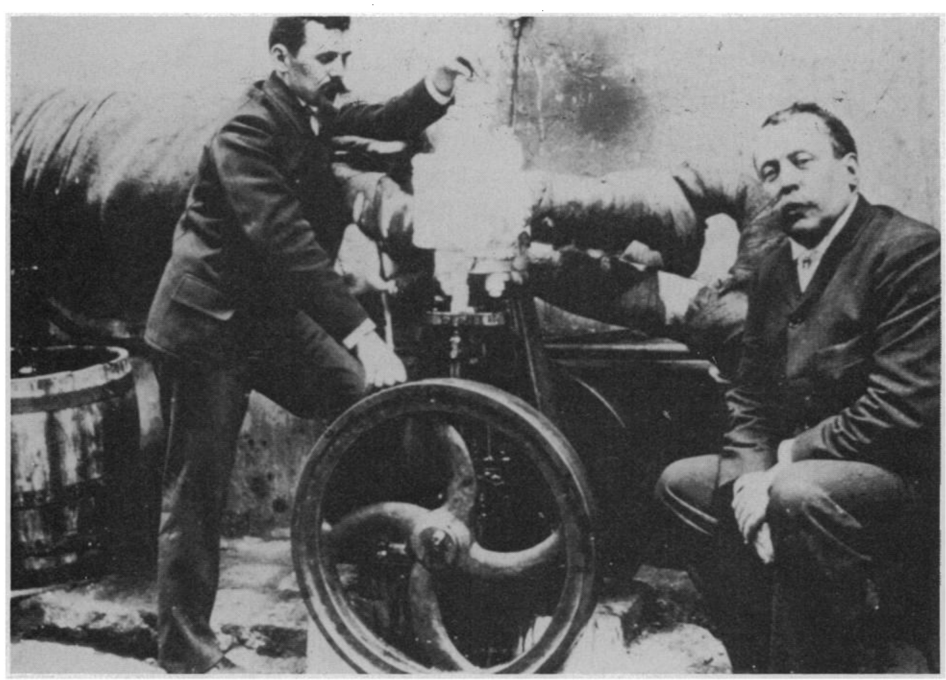
The first major expansion in chemical manufacture was brought about by the growth of the textile industry during the Industrial Revolution. New chemicals reduced dramatically the time required for bleaching, and chemists improved methods for the extraction and application of natural dyestuffs. The growing demands of the textile industry were soon satisfied by completely novel products synthesized from coal tar, the waste of gas works.

Synthetic dyestuffs were the first sector from which a major science-based industry emerged, and after initial successes in Britain and France, Germany came to the fore, as did, to a lesser extent, Switzerland. The wider applications of coal tar intermediates led to the rise of the organic chemicals industry based on aromatics: pharmaceutical products, photographic materials, and explosives. By 1900, artificial indigo, again made from coal tar products, was ousting the important natural product. Although most of these achievements were German, elsewhere in Europe and North America the alkali and acid industries had made tremendous strides. The advent of electrochemistry provided a new route to alkalis. It also made possible the bulk production of aluminum.

The chemical industry entered the 20th century seeking new markets and new technologies. The problem of nitrogen fixation was solved in 1909 by Fritz Haber with his high-pressure ammonia process. The First World War provided the stimulus for the large-scale operation of this process in Germany, mainly because ammonia could be converted into nitric acid for explosives manufacture, thereby overcoming the Allied blockade that denied Germany a supply of Chilean nitrates. The war saw other advances, as well as the introduction of poison gases. Fermentation technology was improved by chemists at first seeking a building-block for synthetic rubber and then producing acetone on a large scale. In the 1920s, quick-drying organic solvents for paints, a spin-off from the fermentation work, and high-pressure routes to synthetic rubber and gasoline were all responses to the demands of the automobile revolution. In the United States petrochemicals threatened coal-based chemicals. Elsewhere, coal-derived acetylene was transformed into aliphatic products. Several firms turned to pharmaceuticals after Bayer produced the first sulfonamide drug. Cartels and trade agreements, as long as they were honored, maintained profits for research and development programs.

The Second World War added further to the demand for novel chemicals, especially the newly discovered polyethylene and nylon. IG Farben's processes assisted the self-sufficiency program in Hitler's Germany. In the United States synthetic rubber research became part of strategic planning. Chemists were called upon to provide new drugs, like penicillin and antimalarials, and plastics and light metals for the war industries.

The postwar world saw the end of the German near monopoly on many processes and products. Nevertheless, the revived German chemical industry remained a model for others to emulate. The phenomenal growth in all nations was interrupted by the oil crisis of 1973, which heralded many changes in the chemical industry, some brought about by environmental concern, others by the threat of financial "raiders" with no interest in long-term planning. Economy of scale was no longer a necessary virtue of manufacture. Companies that had retained the traditional approach based on dye-making



"Georges Claude with the apparatus with which he made the first quantities of liquid air." The oxyacetylene torch, "provided oxygen with its first major markets in welding and metal cutting. From then on, it was no longer sufficient to produce it merely through the Brin process or the electrolysis of water." Claude, who had in 1896 patented a still-used process for dissolving acetylene in acetone, "was working as a young engineer with the Thomson Company when it dawned on him that air was the most abundant source of oxygen, providing it could be separated from its other components." [From *A History of the International Chemical Industry*; courtesy L'Air Liquide] became leaders in fine chemicals. They and others also turned to the specialties market.

This story of the development of chemistry and of its application is the basis of Fred Aftalion's *Histoire de la chimie*, now in an English edition, appropriately entitled *A History of the International Chemical Industry*. Benfey's translation brings over the full drama of the rise of the industry, despite the enormous number of facts and the company mini-histories. The occasional bias toward events in France is actually quite useful, since it provides readers in the English language with a good overview of the understudied French chemical industry. The analysis of how the chemical industries of individual countries, including Japan and the Middle East, have been shaped by sociopolitical factors is particularly illuminating. The translation, unlike the original, includes extensive name and company indexes. This is a useful guide, especially of developments over the past half century.

ANTHONY S. TRAVIS
Sidney M. Edelstein Center for the History and Philosophy of Science, Technology and Medicine, Hebrew University, Jerusalem, 91 904, Israel

Programming Programming

Japan's Software Factories. A Challenge to U.S. Management. MICHAEL A. CUSUMANO. Oxford University Press, New York, 1991. xii, 513 pp., illus. $35.

The business historian Michael Cusumano has followed his successful 1985 study *The Japanese Automobile Industry: Technology and Management at Nissan and Toyota* with a study of Japanese management practices in the software industry. As the subtitle of his new book suggests, Cusumano's implicit hypothesis is that superior Japanese management practices, represented by a commitment to treat software development as just another manufacturing process, threaten the perceived U.S. dominance of the software industry. In contrast with the case of automobiles, where the Japanese success is now obvious, the outcome of Japanese–U.S. competition in software is by no means clear. It is therefore more difficult to tell a convincing story, and the book, despite its length, falls short of proving its controversial hypothesis.

It does, however, clearly demonstrate that Japanese managers' emphasis on continuously improving the software development process by applying techniques commonly used in manufacturing has enabled them to write software programs more efficiently. The book therefore reinforces the important lesson from automobiles that viewing manufacturing as a static and technologically determined function ultimately leads to competitive disadvantage.

After an introductory chapter that lays out the book's conceptual framework, and so contains its conclusions, Cusumano describes the essential challenge for software development—how individuals whose expertise is often tacit can adapt a process that is much like an art form to efficiently write programs of varying language, length, and content. One approach, which Cusumano implies is American, is to manage programmers as sensitive craftsmen working in small teams and to treat each program as a new work of art. The Japanese, in contrast, apply the "factory approach." Cusumano identifies nine elements that typify this approach, and the bulk of the book examines its application inside four Japanese firms (Toshiba, Hitachi, NEC, and Fujitsu) and an early failed attempt inside a U.S. corporation, System Development Corporation.

As one reads the chapters on each Japanese company, a strong sense of the common approach they have adopted does indeed build. First, it is clear that, notwithstanding a historical tendency to centralize programming in large units of several thousand employees, the physical analogy to a factory is misplaced. Technology allows programmers to be geographically dispersed although working together, and NEC, in particular, is moving toward a network of coordinated production sites that exploits this capability. Nor does the factory approach imply assembly-line production using standardized and interchangeable components. Rather it involves a strategic commitment by corporate management to treat software development like any manufacturing process and to focus on building an organizational capability that favors efficiency over the development of unique or breakthrough products.

This process emphasis appears to have been applied in three stages in Japan. Although different companies pursued each stage at different and often overlapping times, a normative prescription for how to implement this, which Cusumano does not explicitly articulate, does emerge. Stage 1 involves implementing the *work methods* of manufacturing. First, development is divided among organizational units so that each "factory" specializes in the type of software that suits it, from generalized business applications, which can be the most standardized, to the most demanding artificial intelligence applications. Second, the software development process is divided into standardized tasks—requirements planning, system design, coding, testing, and so on—in order to facilitate project management. Next, measurement systems are installed to predict and control these individual tasks. Time to write a line of code, number of defects, pages of documentation, and other performance measures are recorded to facilitate forward planning, monitor a project's progress, and identify unfavorable variances that require management attention. Fourth, workers are hired without specific skills (many Japanese programmers are only high school graduates) and are trained and provided a career path inside the firm. In some cases company-specific programming methods necessitate this, but in all cases it serves to minimize skill differences among programmers. The ensuing interchangeability of personnel, Cusumano suggests, allows the Japanese, unlike U.S. software companies, to assign additional programmers to a project and actually reduce the time to project completion. Finally, the well-known Japanese techniques of quality control are applied at all stages. Indeed, standardizing the process, if not the product, facilitates the use of many existing generic techniques and tools for project management, quality control, and cost accounting.

Stage 2 in the application of the "factory approach" introduces *automated tools* to software development after the manual process has been controlled. At first these tools might be simple compilers. Later they become design-support tools that automate coding from standardized design languages or automatically check errors and generate documents. Later still they might be artificial-intelligence tools that translate system requirements directly into code. At each stage these tools are tied to the company's project management system to maintain the emphasis on process efficiency.

Stage 3 involves *standardized components*, or the reuse of modules of code from a library of standard packages. Although this might be the goal of the factory approach, it is clear that it is not yet common—reuse rates, even between similar applications programs, are often less than 20%. Indeed, the initial expense of writing and documenting a flexible module and the fact that starting from scratch is usually cheaper if a substantial portion (around 40%) of a module has to be amended make reuse impractical except for a few functions in general business applications. The Japanese seem to view automated programming and reusability as by-products of their stress on controlling the software development process, not as ends in themselves. In contrast, the few U.S. firms that have tried an approach other than the craft job shop have focused on these as goals and have given up the factory ap-