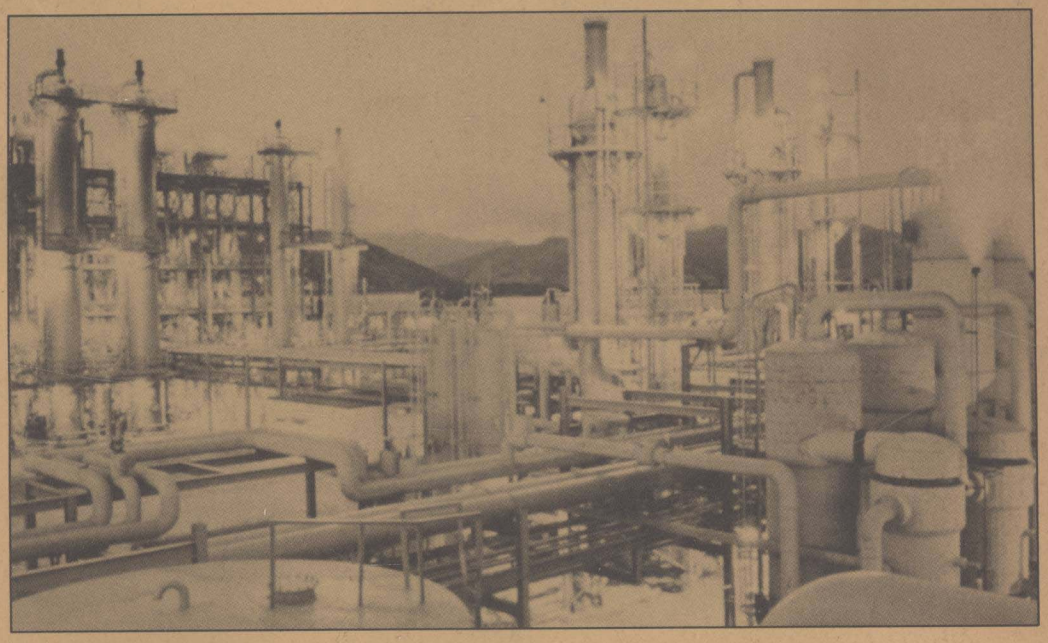
AIChE MODULAR INSTRUCTION

Series G

DESIGN OF EQUIPMENT

Volume 1:
Plant Design and Cost Estimating



AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

AIChE MI

MODULAR INSTRUCTION

Series G:

DESIGN OF EQUIPMENT

Volume 1:

Plant Design and Cost Estimating

James Beckman, Series Editor

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

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INTRODUCTION

In 1975 a new venture in education by and for the chemical engineering community was initiated. Prepared by the CACHE Corporation (Computer Aids for Chemical Engineering Education) and under the sponsorship of the National Science Foundation (Grant HES 75-03911), a series of small self-study fundamental concept modules for various areas of chemical engineering were commissioned, Chemical Engineering Modular Instruction, CHEMI.

It has been found in recent studies that modular study is more effective than traditional instruction in both university and continuing education settings. This is due in large measure to the discrete focus of each module, which allows the student to tailor the speed and order of his or her study. In addition, since the modules have different authors, each writing in his or her area of special expertise, they can be produced more quickly, and students may be asured of timely information. Finally, these modules have been tested in the classroom prior to their publication.

The educational effect of modular study is to reduce, in general, the number of hours required to teach a given subject; it is expected that the decreased time and expense involved in engineering education, when aided by modular instruction, will attract a larger number of students to engineering, including those who have not traditionally chosen engineering. For the practicing engineer, the modules are intended to enhance or broaden the skills he or she has already acquired, and to make available new fields of expertise.

The modules were designed with a variety of applications in mind. They may be pursued in a number of contexts: as outside study, special projects, entire university courses (credit or non-credit), review courses, or correspondence courses; and they may be studied in a variety of modes: as supplements to course work, as independent study, in continuing education programs, and in the traditional student/teacher mode.

A module was defined as a self-contained set of learning materials that covers one or more topics. It should be sufficiently detailed that an outside evaluation could identify its educational objectives and determine a student's achievement of these objectives. A module should have the educational equivalent of a one to three hour lecture.

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Volume 1 of each series will appear in 1980; Volume 2 in 1981; and so forth. A tentative outline of all volumes to be produced in this series follows:

SERIES G: DESIGN OF EQUIPMENT

Volume 1. Plant Design and Cost Estimating

G1.1	Chemical Market Analysis	A. K. Mackenzie and A. L. Thomas
G1.2	Cost Estimating Methods	T. J. Ward
G1.3	Profitability Analysis	T. J. Ward
G1.4	Theoretical Elements of the Mixed Economy	B. K. Harrison
G1.5	Flow Sheets and Diagrams	D. Kauffman
G1.6	Facility Siting and Plant Location—Regional and Community Factors	G. R. Zell
G1.7	Technology Assessment	A. L. Rakow
G1.8	Facility Siting—Environmental Influences, Waste Disposal, Etc.	R. Chawla, M. Hossain and M. Varma
G1.9	Data Sources, Reliability, Updating—Inflation and Relevant Indices	R. Chawla and M. Varma

Volume 2. Storage Vessels and Other Equipment

G2.1	Phase Separation—The Settling of Solids in Liquids	G. H. Kessler
G2.2	Shell and Tube Heat Exchangers in Sensible Heating	J. R. Beckman
G2.3	Materials and Construction for Storage Vessels	J. M. Kalis
G2.4	Storage Vessel Design for Stored Material Integrity	J. M. Kalis
G2.5	Designing Storage Vessels for Safety	J. M. Kalis
G2.6	Determining Storage Vessel Cost	J. M. Kalis
G2.7	Recovery of Benzoic Acid from an Aqueous Stream	A. Sunol and K. Konrad
G2.8	Design of Gas-Solid Catalytic Fluidized Bed Reactors	L. S. Fan and M. H. Peters

Publication and dissemination of these modules is under the direction of Harold I. Abramson, Staff Director, Educational Activities, AIChE. Technical Editor is Lori S. Roth. Chemical engineers in industry or academia who are interested in submitting modules for publication should direct them to H. I. Abramson, Staff Director, Educational Activities, American Institute of Chemical Engineers, 345 East 47th Street, New York, N.Y. 10017.

CONTENTS

Solutions to the Homework Problems are available as a separate reprint from the AIChE Educational Services Dept., 345 East 46th St., New York, NY 10017. The cost is $5.00.

Chemical Market Analysis

Alan K. Mackenzie
and
Arthur L. Thomas

Hull & Co.
Greenwich, CT 06830

OBJECTIVES

Upon completion of this module, students will be able to:

1. Calculate sales in terms of pounds or tons of a chemical product in the coming 5 years and projected sales from 5 to 10 years from now.
2. Estimate the price of a chemical product in the coming five years based on the constant and current dollar.
3. Predict the rate of inflation for the pricing of chemicals in the coming 5 to 10 years.
4. Estimate the market share of a chemical company's product for the coming few years.
5. Estimate the profit margin of a chemical company's product for the coming few years.

PREREQUISITE MATHEMATICAL SKILLS

1. College calculus.
2. Statistics and probability.

PREREQUISITE ENGINEERING AND SCIENCE SKILLS

1. Chemical engineering stoichiometry, unit processes, unit operations, and cost estimating.
2. General and organic chemistry.

Note: Due to the extensive nature of the Study Problems, there are no Homework Problems corresponding to Module G1.1.

INTRODUCTION

A chemical market analysis estimates the demand for chemical products by industry or individual consumers. It obtains facts, evaluates them, and makes short and long term predictions. Market strategies and decisions made by chemical market analysts may determine the thrust of a chemical company's business activity and vitality for years. At a typical chemical company, raw materials are converted into products and the products are shipped out and sold. Dollars are expended to obtain the raw materials and convert them; hopefully, dollars will be obtained upon shipping out the products, *with a profit margin.* This is the free economy system. The basic function of market analysis is to predict the chemical company's expected profits on its existing and potential product lines in the competitive marketplace.

MARKET CHARACTERISTICS OF THE CHEMICAL INDUSTRY

Only from product sales is cash brought into an enterprise. True, there are other ways to raise cash, viz, investments, but, there again, the ultimate return on investment must come from the creation, somewhere, of a product and its sale. Thus, acquiring investment capital, or assets of any kind, and the stability or strength of an enterprise depend on the sale of its product or products.

The quality of the product, in terms of its purity, uniformity, and what activities it can perform, and the timing of its introduction into the market, are two key features of marketing. Sales can be generated by a one-man company or from a multinational company employing over 100,000 persons. In either case, there must be a sales projection of the product. In its simplest form, marketing involves product specifications or technical product bulletins, and in its most elaborate form, advertising in journals and in the audio and audiovisual media, and by the sales efforts of a sales department with branch offices nationwide. All of this must be backed up by technical service and warehouses with a sufficient inventory of product to meet any and all anticipated and unanticipated product sales.

Example 1—Sources of Capital

The prime responsibility of a chemical product is to make a profit. It is this profit, plus other sources of capital available to the company, which makes it possible for the company to meet its expenses and pay for new ventures which hopefully will be successful in the future. There are several sources of capital, in addition to profits, which comprise "venture capital" and which are indicative of a chemical company's "health" or ability to sur-

vive and prosper in the marketplace. Question: What are the sources of capital which a company turns to, to develop the company and its products, permitting it to meet the future in a sound financial condition? Answer: There are four sources. They are debt (borrowed money), depreciation (residue of initial capitalization of equipment and plant), retained earnings or net profit, and new equity from shares of stock. From 1955 to 1970, in nonfinancial corporations, the percent debt of capital sources increased from 41% to 54.4%, the depreciation increased from 32.4% to 38.9%, the retained earnings or net profit decreased from 23.2% to 4.8%, and the new equity share issues decreased from 3.4% to 1.9%. Thus, the most desirable sources of capital, profit and new equity, decreased considerably. This means in turn that the market research will play an increasingly significant role in designing a chemical company's strategy to meet the future.

Market research acts to predict market reaction to a product by predicting sales volume and by suggesting an appropriate price for the product. In the chemical industry, therefore, the market researcher must be equipped with a knowledge of chemistry, chemical engineering practice, and economics.

The purchasers of chemical products may be the individual citizen who makes his purchase in a retail outlet, or they may be wholesalers of chemicals, or they may be manufacturing companies in the chemical industry that purchase chemicals for processing into other chemicals, or they may be manufacturing companies in other industries, such as the fertilizer, steel, automobile, electronics, and rubber industries, all of which require chemicals as an ingredient in one or more processing stages toward the production of their ultimate product or products. Thus, the purchaser and his needs constitute one of and perhaps the most important, market parameters of the chemical industry.

Next in importance as a market characteristic of the chemical industry, is the fact of competition. The product to be sold may also be produced and offered for sale by other companies. Thus, the company in which the market researcher is interested will find for its product, not 100% of the market, but rather a market share, which, of course, may vary from year to year for a number of reasons.

The third most significant parameter or market characteristic of the chemical industry is that it, too, is influenced by political and economic forces, nationally and worldwide. The growth of the chemical industry was greatly influenced by the Civil War, post Civil War industrialization, World War I, the "Roaring Twenties," the "Great Depression" of the 1930's, as well as by the second World War, during which time it grew very rapidly, and after then, when it responded to satiate the needs and wants of a rapidly growing population which sought a higher standard of living.

Other market characteristics of the chemical industry include the factors of new products entering the market and creating the obsolescence of established products; also, companies may cease business, or merge and continue business with different market objectives; companies or product lines may be divested; new companies may start operations and place competitive products on the market.

Example 2—Competition

The silicon chip industry started with the invention of the transistor at Bell Telephone Laboratories in 1947. This led to the invention of the silicon chip in 1959 and the development of the semiconductor industry. In "Silicon Valley," south of San Francisco, in Santa Clara County, has grown the semiconductor chip industry which now has over 80 chip manufacturers. In 1982, Silicon Valley companies controlled 20% of the 16 billion dollar world semiconductor market. Question: What is the future of this industry in terms of product development, new product uses, and markets? Answer: The future is bright, but the industry will remain very competitive on an international basis. The development of robots, dependent on silicon chips, was spearheaded in Japan, which claims half of the world's 25,000 robots. Professors in American universities believe that robots can be developed even further and programmed with common sense. The market for robots will increase greatly in any case. In 1981, the Japanese obtained 70 percent of the world market for 64K random access memory (RAM) chips, before Silicon Valley had one on the market. Despite this, technological innovation, determination, and competitive drive are earmarks of Silicon Valley, which will not only probably meet all competition, but surpass it in the as yet unsatiable market for silicon chips. (Student: Read *National Geographic,* October 1982, "The Chip", pages 421-477. Also, Study Problems 1 through 4 address market characteristics.)

CHEMICAL MARKET RESEARCH, ITS CHARACTERISTICS, AND THE TRAINING REQUIRED TO CARRY IT OUT

Market research is an activity or function that requires the full time attention and dedication of an estimated 5,000 professionals in the chemical industry. Researchers may be active individually, as a consultant, or with a group within a chemical company or within a market research firm, which may have several or many market analysts on its staff.

A market research specialist must be trained in chemistry and chemical engineering from two points of view. First, he or she must understand how chemical products are made, what their characteristics are, and how they are put to use or consumed. Thus, the specialist must have a background in college chemistry, chemical analysis, organic chemistry, industrial chemistry and physical chemistry. Second, the market researcher must be trained in chemical engineering, such that he or she has an understanding of the actual conditions under which products are prepared in the industry on an industrial scale, which involves an approach and expertise quite different from the preparation of chemical products in the laboratory. In the chemical industry, the economic preparation of a product, risking perhaps millions of dollars of capital in-

vestment and providing the livelihoods of hundreds of persons gainfully employed in creating the product, is a serious undertaking for equally serious social consequences. The market research specialist must know how much it costs to make a product using the best industrial techniques before product pricing and the forcefulness with which the product will penetrate the market can be estimated. Chemical engineering training should therefore include a knowledge of stoichiometry, heat and mass transfer, equipment employed in unit operations and in unit processes, and chemical engineering plant design and economics.

A market research analyst must also be trained in economics. One must be keenly aware of the forces that guide the economics in the marketplace of the free market system. The *modus operandi* by which a product can be sold at a profit must be understood. One must be sensitive to the extent of profit margin expected, to the usually sobering influences of competition from other manufacturers, and to the pressures of escalating raw material and manpower costs. One must be aware of the influence of and extent of inflation. A general course in college economics and in accounting is recommended, in order to read financial statements and understand the terminology of finance and economics and how they relate to the "chemical business." Study toward the MBA degree would also be beneficial.

The characteristics of market research involve the capacity of the chemical engineer analyst to obtain information relating to a product and its manufacture, and to assess this information to predict its future sales. The acquisition of technical and market information, both historical and contemporary, comes principally from reading the technical literature and from sales literature from the product manufacturers. In addition, the analyst may discuss the product with representatives of the manufacturers. Predicting future product potential involves the interplay of past performance of the product and its associated industry, such as plastics, fibers, semiconductors, with the predicted interaction of the market dynamics over the short term, say, one to five years, and over the long term, say, five to twenty years. Growth of chemicals may be predicted by the use of linear, higher power, or exponential extrapolations of known performance, as are exemplified in the book, *Chemical Forecasts By Computer* (*2*), which projects the performance of over 700 key chemicals from 1978 to 1983.

Example 3—Predicting The Future of the U.S. Rubber Industry

A chemical market analyst is asked to predict the future of the U.S. rubber industry in the next ten years, and in the next twenty years. What is your prediction? At first glance, one is tempted to believe that synthetic rubber will continue its predominant role, based on the availability of petroleum. Indeed, in Shreve and Brink (*3*) one reads, in italics,

> *For the manufacture of many consumers' chemicals, from carbon black and ammonia through ethyl alcohol and glycol to synthetic rubber, synthetic fibers, and plastics, the petroleum industry provides the cheapest raw materials.*

However, oil prices have jumped from $8.50 a barrel in 1977 to $32.00 a barrel in 1981. This upward trend is expected to continue until world supplies of petroleum are exhausted in the early decades of the next century. Thus, for the next 10 years synthetic rubber will probably predominate, but in the following 10 years it will be challenged by natural rubber. However, the natural rubber industry will have to evolve rapidly to meet the coming challenge. *Hevea* rubber from the Far East rubber plantations is labor intensive; the rubber trees have to be tapped by hand. However, *guayule* rubber from the guayule bush in the American Southwest can be harvested by machine. Although its yield per acre is less than for *hevea,* this may be compensated for, eventually, by agricultural science including plant genetics.

Guayule rubber was once an important factor in the American rubber industry prior to the 1930-1940's, when *hevea* rubber and later synthetic rubber removed it from contention. If guayule rubber makes a comeback in the coming twenty years, what other factors might play a role in the production of rubber? With the decline in the availability of petroleum, such feedstocks as ethylene and butadiene may be produced from ethyl alcohol fermented from huge plantations of cassava and sugar cane in Brazil and other tropical areas. This will be known as "C2 chemistry." These feedstocks may also be produced from methanol from coal by "Cl chemistry."

Thus, one can see that an industry as well established as the U.S. rubber industry is dynamic and evolving and will change in character, probably not in the coming 10 years, but most probably in the coming 20 years. Figure 1 shows natural rubber, synthetic rubber consumption, and reclaimed rubber consumption from 1950 to 1979. Note the decline in natural rubber consumption from 1950 to 1960 with the advent of the synthetic rubber industry, but also that natural rubber consumption increased from 1960 to 1979. Observe the decline in popularity of reclaimed rubber and the influence of the recession of 1975 on the rubber industry. Study Problems 5 through 7 relate to this section of the module.

SOURCES OF INFORMATION, TOOLS, AND METHODS

Any fact, and any intimation of fact that might be a straw in the wind toward predicting the future of the sales or sales trends of a product or product line, are to be latched onto by the alert and conscientious market research analyst. Thus, in the broadest sense, any source is important to chemical market research, whether it is written or verbal. Any written material and any conversation may embody the seed of a thought useful to market research.

Primary sources of information are chemical-economic journals, such as *Chemical & Engineering News, Chemical Week, Chemical Business, Chemical Marketing Reporter, Chem Tech,* and *Chemical Engineering*. Other more financially oriented journals, such as *The Wall Street Journal* and *The New York Times,*

are read to advantage. Other primary sources of information include annual reports of chemical companies and the bulletins published by financial analysts and the institutions or companies they represent (e.g. banks, brokerage firms, and market research firms). Additional important publications include technical and economic ''econotech'' monographs and texts which provide useful background information both on individual chemical products and their cogeners, and on the production processes by which they are made. In addition, monographs on chemical engineering economics, such as *Modern Cost Engineering: Methods And Data,* published by *Chemical Engineering,* belong on the market researcher's bookshelf, as do Riegel's *Industrial Chemistry,* Faith, Keyes, and Clark's *Industrial Chemicals,* and Shreve's *Chemical Process Industries,* and other useful references including publications from government agencies. Still other primary sources of information are experts in the chemical industry, and in government and academia. *Synthetic Organic Chemicals,* published annually by the United States International Trade Commission in Washington, D.C., provides data on production and sales of a number of key organic chemicals. *Current Industrial Reports,* published several times a year by the Bureau of the Census of the U.S. Department of Commerce, relate to production and shipments of numerous inorganic chemicals, as well as clays, fats and oils, and other chemical commodities.

The tools include the ability to evaluate market and production data, to extrapolate them, at least into the near term future of up to five years, and into the longer term future, of up to ten or twenty years. A knowledge of rates of change, as provided by the calculus, and of probability and statistics, as provided by a course in statistics, are a prime tool. Ability to calculate growth rates in terms of linear, polynomial, and exponential analysis, is also a must. At the analyst's desk there should be handbooks of mathematical tables and probability tables, a slide rule, and a calculator with arithmetic, logarithmic and exponential functions.

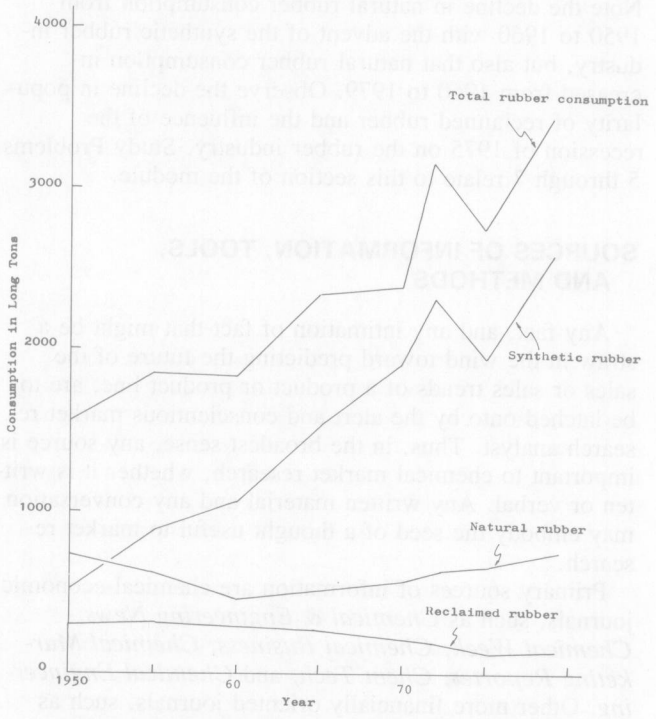

Figure 1. U.S. rubber consumption, 1950-1979.

Another imperative today is an understanding of inflation, and of the value of the dollar in terms of a constant dollar, say, for example, of 1972, prior to the worldwide oil crisis of 1973-74. The analyst should also have a feeling related to the probable course of inflation during the coming few years, based on recent past experience.

The methods of chemical market research involve being able to sift through past product experience and to attempt to visualize a coherent product history that is projectible into the future, at least for a few years. If a product was a poor or mediocre earner in the past, why should it become a good earner in the future? If a company is launching a new product, what will market penetration be in terms of a market that is already filled with competitive products that are good earners? If a company wants to purchase another company to broaden its product line, what influence will the acquisition have on the market of all the products of the new combined company? What influence will the worldwide escalation of petroleum prices have on the pricing of a new petrochemical product? How will government regulations, say, for example, from the FDA and EPA, affect the marketing of a new chemical?

Example 4—Predicting the Market

On April 26, 1982, *Chemical Marketing Reporter* provided a chemical profile on bromine, Br_2. Its uses are:

ethylene dibromide	40 percent
flame retardants	25
$CaBr_2$ and related compounds	20
specialty compounds	10
agricultural chemicals	5
	100

The use of $CaBr_2$ and related compounds as completion fluids in oil drilling muds is growing rapidly. New specialty flame retardants are boosting growth of bromine chemicals. Also, bromine specialty compounds for water treatment and in agricultural chemicals show promise of growth. However, the ethylene dibromide market is expected to decline and level off, depending on whether regulations on leaded gas are relaxed. Would the market for bromine grow, hold level, or decrease from 1981 to 1986?

Answer:

Chemical Marketing Reporter, taking all things into consideration, predicted an increase in demand from 378 million pounds in 1981 to 389 million pounds in 1982 and 455 million pounds in 1986. CMR opts for the market strengths being greater than market weaknesses (decline in ethylene dibromide market) in the five year interval of prediction.

The market analyst, faced with a bewildering array of product influences, realizes at once that it is impossible to predict the future with 100% certainty. He or she can make estimates, and with native acumen and expertise, mathematical functions, and "gut feeling" for the behavior of the chemical industry, should succeed in achieving a high degree of success. Still, the old sayings, "there is nothing more certain than change," and "the more things change, the more they stay the same," may apply. In terms of marketing a product, one is cognizant of the admonition of "look before you leap" and "he who hesitates is lost." Thus, an element of bewilderment cannot escape market analysis, and it is with the mysticism of market research that one can boldly and rationally face the future, but not be able to solve completely what it ultimately is, imponderable and a mystery.

Before looking with some detail into the processes of chemical economics, price forecasting, and prediction of market penetration, try Study Problems 8-11 at the end of this module.

CHEMICAL ECONOMICS, PRICE FORECASTING, PREDICTION OF MARKET PENETRATION

Chemical economics is similar to the economics of any industry in the free market economy and in the free world. It involves the economics of production and marketing within the country of origin and of trading raw materials and products among countries. Prior to World War II, chemical economics focused primarily on the activities in the U.S. and in western Europe, but since World War II, the Orient and especially Japan, have become equally active in chemical production and trade. Even more recently, the industry is witnessing the nascence of Mexico and South America as centers of a brisk chemical industry. The second World War also launched Russia as a major chemical producer and only recently, has the free world formed a staging area of technical thought and expertise to also bring mainland China into the global arena as a major chemical producer. Thus, the entire world, sooner or later, will become active in the manufacture and distribution of chemical products, culminating an "industrial revolution" that started in England in the 1700's, and with the science of chemistry, whose origins were sparked by Lavoisier, Berzelius, Dalton, and other leaders in science, also in the 1700's.

This preamble was included to indicate to the student that chemical economics is becoming increasingly global in scope, and as the chemical industry matures, competition in the chemical industry worldwide will not decrease. It will be up to the well-honed market analyst to provide responsible decisions to encourage the active marketing of quality chemical products to domestic and overseas markets.

Example 5—Sphere of Interest of a Typical Chemical Corporation

The headquarters of the Hexcel Corporation are located in San Francisco, California. Does this signify offhand that its principal activities in chemical production would be on the West Coast of the U.S.?

Answer:

No. The Hexcel Corporation makes structural materials, specialty chemicals, and resins worldwide, in the U.S. (i.e., Arizona, New Jersey, Ohio, Pennsylvania, Texas and Michigan), Belgium, France, England, Spain and Japan. It employs over 2,000 persons and has over 3,000 investors of its stock listed on the New York Stock Exchange.

It took 5000 years of historical life to 1750 to produce and support a population of two billion persons; it required only 200 additional years to increase the global population by another two billion persons; population experts predict that it will require only two decades, 1980 to 2000, to increase the global population by an additional two billion persons. These facts and predictions are stressed because the chemical market analyst of the 1980's and 1990's will be studying problems involving supply sources for raw materials and the distribution of chemical products to a world demanding an increasingly higher standard of living whose attainment is becoming increasingly elusive. Thus, chemical economics and chemical marketing research will become increasingly complex and will require the best efforts of proficient analysts. It will be to them to minimize economic dislocations and provide for a fluent and frictionless exchange of raw materials among nations and companies, and to optimize the availability of chemical products to the various chemical markets.

Example 6—International Chemical Economics

In December 1982, President Reagan visited Brazil and while there, advocated more free trade among countries and less protectionism. Brazil has great potential to produce ethyl alcohol by fermentation of its abundance of cassava plant roots and sugar cane, to meet not only its requirements, but the requirements of other nations, such as the U.S. What do these two factors mean to the U.S.?

Answer:

The U.S. faced a shortage of petroleum from which to make gasoline to run its automobiles, buses, and trucks. These vehicles can be easily adapted to run on ethyl alcohol. Without protectionism, the U.S. could either purchase Brazilian alcohol at a reasonable value for cash or could exchange it for high technology products made in the U.S.

As noted earlier, chemical economics run parallel to the economics of any industry. The chemical company may run the gamut from one-man to about 100, to several hundred, or to several thousand persons. The more persons employed, the greater diversification of function, and the greater the magnitude of purchasing raw materials and selling chemical products. Creativity relating to the development of new products may reside with small groups using the Edisonian approach, to larger groups which rely on team efforts and sophisticated equipment to place large and costly engineering projects into motion, to mass produce quality chemicals at a minimum cost. The market analyst may be called upon to assist small, medium, or large companies to place their products on the

market competitively. The analyst should be aware of the differences among companies and of the needs and objectives of the company or companies he or she serves.

Thus, a complete grasp of costs is the preamble for the analyst to forecast price. The analyst must estimate a price at least as great as cost, all the while being aware of the competition's pricing of the same or similar product. There are also state and federal regulations regarding pricing and profits. The analyst must also attend to the fact of inflation and what influence it will exert on pricing, in terms of escalating costs and the buyer's possible decreased ability to purchase the product. One must be knowledgeable on how to cope with times of recession, which influences pricing.

To forecast pricing effectively, the market analyst should read econotechnical literature constantly and avidly.

Prediction of market penetration depends on the situation the product being marketed is in. Here are several possibilities:

1. The product is new and is going to compete with an existing product, such as plastic bottles introduced to compete with glass bottles.
2. The product is not new and is going to compete with an existing product, such as starting up a facility to manufacture and market aspirin.
3. The product is not new, but it is going to be produced for a new or revitalized use, such as ethanol as a fuel to be blended with gasoline.
4. The product is new and is novel in the sense that it has no or virtually no competition, such as DDT when it first appeared, or penicillin, when it first appeared.

Other factors include the capital available to back up the product's entry into the market. The company may have to wait a number of months or one or more years before the product ''takes'' or finds its place in the market. It has to be promoted by advertising and other active efforts of the sales department. The waiting, and the cost of production and warehousing and sales prior to the product's becoming a source of revenue, require a considerable amount of capital and the company must be capable of accepting this responsibility.

Of the four listed instances of product entry, the fourth, a new product with no competition, is ranked as the most ideal situation. A real need exists; a unique product has been developed to meet the need. In terms of the market, it is almost ''sure to be a winner.''

Situation (3) must also be ranked highly. Startup for a new use usually means the market practically demands the product to help solve a ''market crisis'' for such a product. Situation (1) also has a high rank, particularly if the properties of the new product are highly favorable. Plastic bottles, for example, are light in weight and can be easily carried, they bounce on the floor rather than breaking; and, like glass bottles, they can be recycled. Situation (2) is probably the most mundane of the four possibilities, but in terms of finding a market, can be rewarding also, especially if the product can boast a cost-cutting new manufacturing method and/or if it can be made at a higher purity and quality, among other features. Also, as the population and number of consumers is on the increase, new production facilities to make a product are welcome in providing another source of supply which may be closer to the market it serves than other sources of supply.

Still another factor is the cost to manufacture the product. If the product is novel and the pricing can be kept down, the product is sure to enter the market with a ready acceptance. If the product offers a new use and the price is reasonable, the product will generate considerable interest. This is true if the product is new on the market; plastic bottles have certainly found a place in the market in a short time, one compelling reason being that their ''price is right.'' If the product is not necessarily new, but is competitive in quality and price, it, too, will find a place, such as the rubber tires of a tire company entering the domestic market for the first time.

Thus, the chemical market analyst must be alert to manufacturing cost, product properties, the characteristics of the market, and the capability of the company to launch the product. By avidly reading about the mode of entry of other chemical products into the market over the past few decades, the analyst will acquire a good grasp of entry characteristics of the scores of successful chemical products that have won acclaim by consumers. This is the best guide to predictive analysis. Try Study Problems 12–16 now.

CHEMICAL MARKET RESEARCH AND THE USE OF THE COMPUTER

Computers have three basic uses (other than tutorial) to chemical market research. First, they can be used as sources of data and information, and in this role, are called data banks. Second, they can be used as calculators to perform projections or forecasts several years into the future. Third, they can be employed to perform complex calculations to solve systems of models descriptive of perhaps a production and sales unit, company, or industry, and the forces that act upon them, such as cost factors, raw materials availability, factors that influence product pricing, and market demand for the product.

The first use is the most easily learned and requires only a few hours practice. The skill to use the computer as a calculator depends only on the mathematical background the chemical market researcher has acquired in his or her study of chemistry and chemical engineering. Ability to make models and derive complex equations that describe their operation probably requires a degree in applied or engineering mathematics.

The Computer as a Data Base

The chemical market researcher should be aware of what data bases are available or will be available, and how to use them. Some data bases are listed in Table 1.

Every data base requires one to be knowledgeable about search command language for the data base; this language varies from data base to data base.

The shortcoming of data bases is that they respond to commands or key words given to them by providing ar-

Table 1.

The Information Bank I and II

The New York Times Information Service Company, Parsippany, New Jersey
Over two million abstracts of news and editorials published in The New York Times since 1969 and information from ten other newspapers and fifty magazines.

Nexis

Mead Data Control
New York, New York
Provides full text articles in The Washington Post, Newsweek, Dun's Review, The Economist, and other magazines.

Compustat

Standard and Poor's Corporation
Englewood, Colorado
Financial and other data for all publicly owned corporations are offered, as well as the type of goods produced for about 6,000 companies.

Dialog

Lockheed Missiles and Space Company, Inc.
Palo Alto, California
This service has access to over 40 million references to journals and newspaper articles in over 100 data bases covering all areas of science, technology, business, medicine, social science, current affairs, and humanities.

ticles and abstracts they find in the data base that contain the key words. Thus, information peripheral to the searcher's interest may be generated, providing unnecessary or unwanted information in addition to the main subject of interest.

For example, suppose a researcher wanted to learn about ethyl alcohol produced from sugar beets. Entered on the computer are at least the key words "ethyl alcohol," "sugar beets," and "manufacture." If this is all the data base system is told, it may output articles and abstracts on ethyl alcohol from sugar beets for the past ten years, without reference to prices or process details or plant locations, any of which may be the researcher's chief interest. In other words, data bases are not perfect. Information is coded by the data base, and this coding may not correspond with what one has in mind for a search. See Study Problem 17.

Chemical and financial libraries remain a great source for information retrieval for chemical market researchers. Libraries are inexpensive to use, they are reliable, and their information can be readily targeted and obtained, providing as exact answers as possible to the searcher's questions.

The Computer in Forecasting

Faust wished to be omniscient—a wish that we, as students, all share, with respect in particular to knowledge about the future. However comfortable the present may be, there is no certain way to predict what the morrows will bring. This is true not only in economics, global strategies, the weather, and day-to-day living, but also in the production of chemicals.

The simplest way to forecast is based on past experience. If a product's manufacture increases linearly every year, the most reasonable prediction is that it will continue to do so during a reasonable period of prediction, say, the next five years. If the past history is linear, parabolic, exponential, or quadratic with respect to time, then it would be reasonable to predict a continuation of this trend in the coming few years. However, the product may be nearing market saturation, and its production may taper off, producing an S-shaped curve.

It is the discontinuities in a product's production history that would make Faust tear his hair or climb a pole, and there are at least five types of product discontinuities. They quite often happen unexpectedly:

1. New markets for a product develop. When fuel from petroleum became scarcer and higher priced, a market for motor fuel from ethanol grew. To produce that ethanol, great new plantations of corn, sugar cane, and cassava emerged, from which the ethanol will be produced.
2. New technical conditions develop. Developing countries are creating a large market for soya bean oil and meal. Soya bean crops are being planted extensively in Brazil. To replenish the soil, the leguminous peanut plant is planted in rotation with the soya beans. Thus, an abundance of peanuts, peanut meal, and peanut oil is created, for which markets must be found.
3. Short supply conditions develop. Chrome is now in short supply, such that it is being replaced on automobile bumpers by rubber and plastics. Thus, a new market is emerging for rubber and plastics, although they may be considered inferior to chrome for this purpose.
4. The main supplier raises his prices. This is what happened when OPEC in 1973 drastically increased the price of a barrel of crude oil. This price was reflected in the price of petrochemicals. Thus, interest was generated to make "petrochemicals" from coal and biomass; a synthetic fuels industry develops.
5. A superior product appears in the market at a competitive price. Ultramarine blue was the principal blue pigment manufactured until it was somewhat displaced by the advent of iron blue. Then, in 1934, phthalocyanine blue was discovered. It can be made inexpensively from urea, phthalic anhydride and a copper salt, all abundantly available, and its properties are superior to ultramarine blue and iron blue, which have largely been displaced.

Forecasting in chemical market research involves, usually, plotting production (or price) in a consecutive number of past years (say ten or twenty) and then extrapolating the data for a period of, say, five years into the future. To accomplish this, a best straight line may be fitted to the data (linear regression); an exponential curve may be fitted to the data, a quadratic equation may be plotted; or a number of independent variables may be assumed (multiple regression) and the data fitted to them and extrapolated over the next five years. In summary:

1. straight line (linear regression)

$$y = ax + b$$

2. exponential curve (exponential regression)

$$y = ae^{bx}$$

3. quadratic equation (2nd order regression)

$$y = ax^2 + bx + c$$

4. several independent variables (multiple linear regression)

$$y = ax_1 + bx_2 + cx_3 + \ldots$$

where x_1, x_2, x_3 ... are independent variables.

Since there are a number of points, say ten for the ten past years, or twenty for the twenty past years, the curve or line for past history can be drawn in, approximately, by hand, or it can be calculated statistically by computer. [Reference (*4*) lists BASIC programs for linear, exponential, *n*th-order and multiple linear regression.]

In solving multiple regression for forecasting production of chemical products, a number of independent variables or indices come to mind, such as gross national product (GNP), industrial production index (IP), index of industrial activity, productivity index for chemicals and allied product, CPI (chemical process industry) output index, and CPI operating rate. The last four of these indices are published regularly in *Chemical Engineering*. The CPI output index and operating rate are not to be confused with another economic index, the CPI (consumer price index). See Study Problem 18.

LITERATURE CITED

1. "The Chip," *National Geographic,* p. 421–477 (October, 1982).
2. "Chemical Forecasts by Computer," Hull & Co. (1979).
3. Shreve and Brink, "Chemical Process Industries," 4th ed., p. 652 by permission of McGraw-Hill (1977).
4. Poole, L. and M. Borchers, "Some Consumer Basic Programs," 3rd ed., Osborne/McGraw-Hill, Berkeley, CA (1979).

STUDY PROBLEMS

1. Draw what you think is an appropriate box diagram of the factors or market characteristics of the chemical industry which will influence the total sales of the market a product will enjoy.
2. Dyes are a recent example of a successful and important product line of a major chemical producer that was discontinued or sold to another company. Why? Discuss. Sulfuric acid is a chemical that was made in colonial times and is still manufactured today. Why has it not been displaced?
3. Plastic bottles are an example of a new product based on chemical technology that has replaced a heretofore highly successful and well-established product. What are the reasons?
4. Given the total production of the "Top 50" U.S. chemical companies during 1964–1981 (Table 2), plot the production versus year. What do you conclude as to the health of the market of the U.S. chemical industry?

Table 2. "TOP 50" Production of Chemicals 1964–1981

Year	Production Billion Pounds	Year	Production Billion Pounds	Year	Production Billion Pounds
1964	250	1970	390	1976	460
1965	280	1971	385	1977	500
1966	320	1972	430	1978	530
1967	340	1973	450	1979	560
1968	360	1974	465	1980	550
1969	380	1975	430	1981	540

5. From the following, which three examples sell directly to the individual consumer and which sell to other companies for further processing?

   Aspirin
   Propylene Oxide
   Calcium Hypochlorite
   Ethylene
   Calcium Chloride
   Cyclohexane

6. What prior experience would be useful before starting a career in chemical market research? List at least five different activities in industry or at universities.
7. Chemical reactions and chemical technology yield a chemical product. The difference between the cost of manufacture and sales and the sales price is the profit or gross return to the enterprise that manufactures the product. What do you consider to be a reasonable profit, not only for immediate gain, but in terms of the long term aspirations of the enterprise? 5 cents on the dollar, 10 cents, etc...?
8. Individuals who work, like companies, also make a profit, although they don't think of it in these terms, in the sense that their personal income minus expenses is invested in bank savings accounts, stocks, bonds, and so on, to help provide for their future. In what other ways are individuals similar to companies in trying to predict the future?
9. If a chemical product showed a linear growth in sales during 1970–1975, and a somewhat exponential growth during 1975–1980, what sources of information would you study or consult and what tools would you use to predict whether the growth rate will return to a linear mode, will continue to increase exponentially (at the same or different rate), reach a plateau, or begin to decrease?
10. An energy crisis is also a materials crisis. Oil is the basis of the petrochemicals industry—the source of plastics, films, bottles, building materials, pharmaceuticals, and so on—but if its supply should run out, alcohol may replace it and become the basis of the alcohol chemical industry. What technical and

economic sources of information, tools, and methods would you use to predict the growth and extent of growth of the new alcohol chemical industry?

11. In the 1930's, bread cost 5 cents a loaf; a postcard cost 1 cent, a bus ride cost 10 cents, a new automobile cost $500. What sources of information would you consult to find the price of chemicals in the 1930's? Have the prices of chemicals since then been less than, equal to, or greater than, on the average, the rate of inflation?

12. You are the market analyst in a chemical company that plans to acquire a division of another chemical company that makes a different, but popular, chemical product. This acquisition will bring, therefore, a measure of goodwill to your company. What methods would you use to predict whether the acquisition will be beneficial to your company?

13. Given, in Table 3, for the years 1899 to 1980, the U.S. population, the value added by chemicals manufacture in the U.S., and the value of the dollar (taken to equal $1.00 in 1967), compute the value added by chemicals manufacture from 1899 to 1980, per capita, and draw two curves:

    1. The value added per capita in terms of the real dollar. (Note: real = actual = current $.)
    2. The value added per capita in terms of the constant 1967 dollar.

Table 3. Note that the Value of the Dollar is 100 Divided by the Consumer Price Index. If the CPI is 50, the Value of the Dollar is $2.00.

(Sources: U.S. Population from *Statistical Abstracts of the U.S.*, Bureau of the Census. Value Added by Chemicals Manufacture in U.S. and Value of the Dollar from *Historical Statistics of the U.S. Colonial Times to 1970,* Bureau of the Census.)

	I U.S. Population in 1000's	II Value Added By Chemicals Manufacture in U.S. in million $	III Value of the Dollar (1967: $1.00)
1899	74,799	212	4.31
1904	82,166	286	3.82
1909	90,490	401	3.64
1914	99,111	457	3.32
1919	104,514	1,198	1.93
1923	111,947	1,185	1.96
1927	119,035	1,474	1.92
1931	124,149	1,359	2.19
1935	127,362	1,363	2.43
1939	131,028	1,819	2.40
1947	144,126	5,317	1.50
1950	151,684	7,237	1.39
1954	162,391	9,547	1.24
1960	180,671	14,415	1.13
1965	194,303	20,956	1.06
1967	198,712	23,746	1.00
1970	204,879	27,930	0.86
1975	215,692	44,976	0.62
1980	226,505	73,385	0.41

Table 4.

Year	U.S. Crude Oil Price, $/U.S. barrel (42 gallons)	Ethylene, Cents/Pound	Butadiene and Butylene Fractions, Cents/Pound
1970	3.18	3.1	3.1
1972	3.39	3.0	2.7
1974	6.74	7.5	5.9
1976	8.14	11.2	8.7
1978	8.96	12.5	19.5
1980	20.89	22.0	27.0
1981	31.77	25.0	21.0

Sources: Column 1, American Petroleum Institute
Column 2 and 3, U.S. International Trade Commission

What do you observe and conclude? Note that the dollar has two values, its actual real value and its constant value. If a loaf of bread cost 15 cents in 1939 and 65 cents in 1980, these are actual or real prices. However, if we assume the dollar to be constant in 1939, equal to $1.00, then the dollar in 1980 is inflated, and its value in terms of the 1939 constant dollar is $15/65 \times \$1.00 = \$0.23$ or 23 cents.

14. Given Table 4, plot the price of oil in $/barrel at two year intervals from 1970 to 1981. Similarly, plot the price of basic petrochemicals such as ethylene and butadiene during the same time. What do you conclude as to the dependence of chemical products on the price of their raw materials?

15. Given the price history curves of several major inorganic chemicals, such as lime, aluminum, sodium sulfate and sulfur (Table 5), and three typical organics, ethylene, butadiene and butylene fractions, and benzene (Table 6) for fifteen years, what do you

Table 5.

	Inorganic Product				
Year	Lime $/ton	Aluminum cents/lb., primary ingot	Sodium Sulfate $/ton	Sulfur $/long ton	Consumer Price Index
1941	7.06	16.5			44.1
1945	7.76	15.0			53.9
1950	11.13	17.7			72.1
1955	12.13	23.7	~27	29.7	80.2
1960	13.35	26.0	28.6	23.1	88.7
1965	13.87	24.5	27.3	22.5	94.5
1970	14.53	28.7	21.5	23.7	116.3
1973	17.35	~31.4	21.1	17.8	133.1
1974	21.92	34.1	26.9	30.5	147.7
1975	27.38	39.8	43.4	50.2	161.2
1976	30.11	44.5	56.1	51.2	170.5
1977	33.42	51.6	47.6	50.0	181.5
1978	36.67	54.0	50.0	49.6	195.4
1979	41.18	61.0	55.7	60.8	217.4
1980	44.34	71.6	72.50	98.9	246.8

Table 6. Organic Product

Year	Ethylene cents/lb.	Butadiene and Butylene Fractions cents/lb.	Benzene cents/lb.	Consumer Price Index
1941				44.1
1945	2.4	~2.7		53.9
1950	4.2	2.7	5.1	72.1
1955	4.7	2.9	5.9	80.2
1960	5.0	2.7	4.4	88.7
1965	4.0	4.2	3.3	94.5
1970	3.1	3.1	3.0	116.3
1973	3.3	2.7	4.0	133.1
1974	7.5	5.9	9.0	147.7
1975	8.8	10.3	9.6	161.2
1976	11.2	8.7	10.6	170.5
1977	12.0	18.8	10.4	181.5
1978	12.5	19.5	10.1	195.4
1979	14.0	21.0	18	217.4
1980	22.0	27.0	13	246.8

conclude, by correlating your information, as to price forecasting for this group of chemicals for the following five years? Ten years? What effect do you think the predicted rate of inflation will have on the pricing, based on past experience? In other words, will this group of heavy chemicals be more price or inflation resistant than other groups of chemicals, such as the organics?

16. Cando Company has developed a new chemical product, a detergent that by far excels other detergents, pound per pound, in cleansing power. It also has no toxic ingredients, is easily biodegradable, and is not harsh on the hands. It is called BEST-OF-ALL. Cando Company was founded by Mr. Iam A. Wizard, who graduated with a chemical engineering degree from Studious & Imaginative Tech in Learnville. He developed the detergent in his garage in Doerstown after several years of experimentation. Mr. Wizard has only several thousand dollars and is, therefore, short on capital. He knows that to market his product, he needs people to make and sell it; he needs plant space, perhaps an abandoned factory that he can inexpensively refurbish; he needs equipment, most of which he can purchase second hand; he needs to purchase raw materials; he needs to pay for advertising and selling expenses. He needs to raise capital, but the banker who lends the money, Mr. Reasonable Skinflint, will want to know the risks involved, namely, what share of the market will the product probably take; what should be its introductory price to do justice to its remarkable cleansing action, and to meet competition, and to comply with the fair trade law; and to at least meet costs. Mr. Wizard is a real wizard, because he knows the best way to find the answers is to obtain the services of a market research firm at which he will spend part of his savings to obtain an authoritative study. You are the chemical engineer market analyst and you are asked to conduct this market and cost analysis for

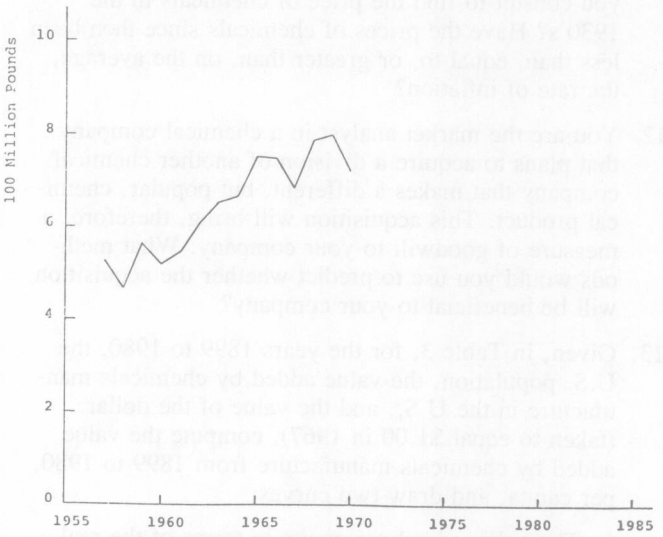

Figure 2. U.S. production of carbon disulfide.

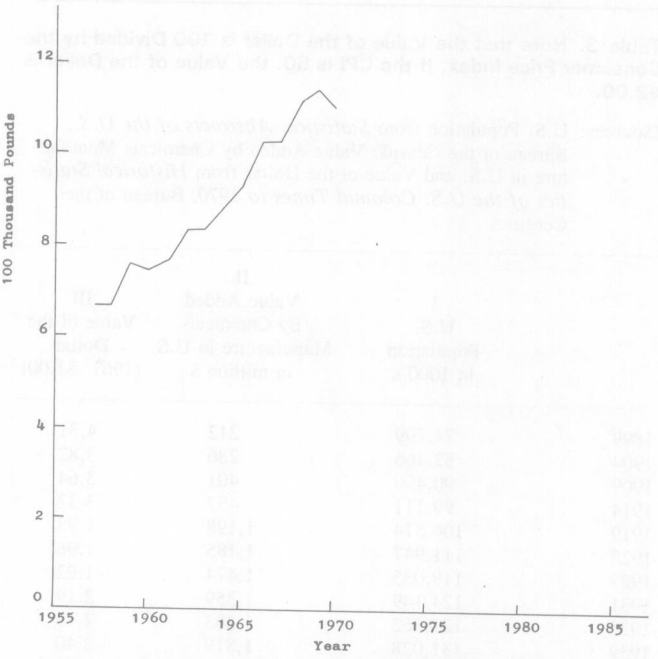

Figure 3. U.S. production of cellulose esters and ethers.