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Technical research in the chemical and process industries as an aid to management

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Technical Research in the Chemical and Process Industries as an Aid to Management

by

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CHAPTER I

INTRODUCTION

Industrial research is probably the most effective mechanism ever devised by man to improve his standard of living. As C. E. Wilson, President of General Electric, said in an address a short while ago,

> If it were not for industrial research we would not be here - literally. I know of nothing so characteristic of the pattern of American economic growth, or so compelling in its results - on competition, on progress, on our whole national life - as this one factor.[1]

These words illustrate the role that research plays in the economy of the country today, and it is partly through its aids to managerial techniques and problems that research has achieved this position of importance.

The industrial group in the United States that requires the greatest emphasis on research is that of the chemical and process industries. This group not only utilizes research as a means of developing new products but requires its services in order to maintain its competitive position within the industry itself. This is well demonstrated by the fact that 60% of the sales of the E. I. DuPont De Nemours and Company in 1948 consisted of products that were not in commercial production in 1928,[2] and that 20,000 employees of another company were engaged in the manufacture of products

1. Public Utilities, Dec. 4, 1947
2. Trends in Industrial Research by Dr. Weidlein, Director, Mellon Inst.

that were not in commercial production in 1936.[1] No similar examples of the direct results of research on the industrial scene can be given by any other industry.

One of the most difficult jobs that has faced the scientific leaders of this industry is to convince the rest of industry, or at least large portions of it, that research pays in the long run and that new knowledge is the springboard from which is launched the future progress of the nation. Although this study attempts to show only a few of the many advances made in the chemical industry through research, and their direct relationship to managerial problems, it will be another step towards making its importance a universally proven and recognized fact.

1. Standard & Poor's Industrial Surveys, Chemicals, May 5, '49

CHAPTER II

ROLE OF RESEARCH

Past centuries have brought many developements and ideas from the imaginative mind of the inventor. In the period before the turn of the century he had one of a number of reasons for pursuing his quest of the unknown: with some it was a search for a specific result, as in the case of Charles Goodyear and vulcanized rubber; with others it was just a desire to perform or apply certain knowledge or information, exemplified by James Watt and the steam engine; while with a small minority invention was pursued as a means of making a fortune, as in the case of Elias Howe and the sewing machine.[1]

The approach of the twentieth century saw a change in the size of the industial enterprise. The processes for production grew larger, as did also the companies and trusts that were fed by the increasing profits. This was reflected in the opportunities for the inventor by requiring him to have much more complete and diversified equipment at his disposal, both for producing his inventions and for testing them, before he would dare and offer them to industry as a proven article. He was therefore slowly forced out of the picture unless he could find a beneficient financier willing and able to support and further his inventive genius. It was during this time that Thomas A. Edison brought about his

1. Scientific American, January 1945

revolutionary change in the capabilities and usefulness of the individual inventor. In carrying on his numerous investigations involving electric light, the phonograph, and the motion picture, he found that whenever he uncovered a fact in any one of these new fields it was just as though he was opening a front door to a whole house of facts. All of these unopened doors forcibly impressed upon him the limitations of individual investigations and he therefore conceived the idea of hiring assistants skilled in one of the various fields of research to open these doors for him and to explore beyond. Industrial research was born of this revolution.[1]

This very enthusiastic start in research on the American industrial scene was, however, short lived and did not attract the minds or the money of entrepreneurs until it was forced upon them forty years later. At the time of World War I there were only two well established research laboratories in the United States, both of which represented fields in which America had always been, and still is, ahead of the other technically minded nations, namely electric lighting and telephony as represented by the General Electric Company and Western Electric Company respectively. The first World War awoke the American public to the realization that their wealth had come largely from the soil as contrasted with that of Germany which had derived its wealth mainly from its

1. Ibid

utilization of brains, or the success in developing wealth from intellectual sources. America lead the world in wheat, cotton, and crops in general; steel, copper, and most other metals; coal, oil, and other products from the earth. Gèrmany's industrial leadership, on the contrary, was based for the greater part on scientific and technical achievement. Germany had a practical monopoly in dyes, optical glass, potash, drugs, chemical reagents, and many special alloys and metals like magnesium.[1]

The emergency of the first World War finally made the country realize that its shortcomings in the field of industrial research would seriously hamper its chances of bringing the conflict in Europe to a speedy end in favor of the Allies. To remedy this situation in the shortest possible time all men and women in the United States with the background and aptitude for research were pressed into scientific service before the time of the Armistice in 1918. The record of this research, drummed up at such short notice, is really remarkable. Although the Germans had made the statement that the United States could not manufacture aniline, due to the fact that the benzene from American coal was not the right grade, this country was producing 37 million pounds of aniline per year by 1917. In addition to this no small achievement, potash was produced for the first time, sulphuric acid was manufactured by the contact method without

1. Research and the Public by L. A. Hawkins

the need of bulky lead chambers, optical glass was manufactured, and many chemicals, including photographic which had previously been bought from Germany, were synthesized for the first time in this country.[1]

American industry was thus finally given the proof that its scientists could achieve such a surprising standard of success when called upon to do so. This resulted in increasing emphasis being placed on the establishment of research centers for industry, so that by 1920 there were over 300 laboratories engaged in industrial research employing about 9,000 full time research workers.[2] This was the foundation of our research program as it exists today in the larger corporations and industries, though the smaller companies are finding out that even in their own limited fields there is considerable room for research. No more need be said in this regard than to give a comparison of expenditures for research, and total number of employees, during two periods twenty years apart. Expenditure on research rose from $217 million in 1927 to $1,160 million in 1947, while employment rose from 30,000 to 140,000 during the same period.[3]

Research has by no means only one objective, namely that of producing new products. This conception is as far away from the truth as if the statement were made that

1. The Functions of Industrial Research by Dr. E. C. Bain
2. Ibid
3. Management Review, July 1929

the results of research affect management directly in only one way, namely the additional profits to be obtained from the production of the new products. The relationship between research and management covers very many fields, as is well demonstrated by a referrence to competition as it exists in the chemical and process industries. In the typical industry, normal competition is between essentially similar products on a price, quality, and service basis. In the chemical industry, however, four separate competitive phases are distinguishable, all of which must be given full support by the efforts of the research department: a) that between identical products of different companies, b) that between the same products derived from different raw materials, c) that between the same products made by different processes, d) that between different products designed to serve the same purpose.

Management's most important and basic function is to increase the sales of the product it is manufacturing. The life blood of any industry is its sales, and these have to be obtained largely through the medium of overcoming sales resistance initially present in the consuming public. It is the function of advertising to assist in overcoming this sales resistance, but no amount of advertising will sell a product unless the utility and quality of the article are demonstrated to the consumer. This appeal will be greatly enhanced if the article is being sold at a price that the purchaser can well afford to pay. This may be demonstrated when a consumer purchases soaps for use on the floor(Noctil), with dishes(Glim), and with fine laundry(Lux Flakes), where the strength and cleansing action of the soap is compared and weighed against the price. It is due to research that these numerous differentiated products have been placed on the market to aid the consumer in performing the menial tasks of everyday life at a price he can well afford.

A similar purpose as that mentioned above may be accomplished by the research department improving the products on the market, either in appearance, function, or the variety of its uses. Though both the methods mentioned thus far will increase sales considerably, there is nothing that achieved the same results as those obtained from putting a completely new product on the market. If a product is really new, has specific properties and uses, and is priced right, it will sell on any market, buyers or sellers.
Du Pont's newest plastic demonstrates this point exceedingly well, in that this plastic, Teflon, is completely resistant to all chemical action, except that of molten alkali metals, and due to these unique properties has caused a considerable stir in the field of coatings and containers. Although the product is at the present time only being produced in pilot plant quantities numerous companies have asked permission to use Teflon in the lining of tank cars and other containers

for the transportation of chemicals.[1]

The three methods mentioned thus far for improving the sales of a company are all directly connected with the industrial research laboratory from where the original ideas and products come, and it is up to management to utilize these capabilities of the research laboratory to the utmost in its efforts to increase sales and keep the company ahead of its competitors.

While industrial research is occupied in the work of increasing sales in one of the various methods mentioned above, some of the research workers may be conducting experiments in their search for a specific new substance and come across a by-product which is outside the scope or purpose of the study itself, and therefore overlook it for the time being. Very often further study and analysis of these by-products result either in their application to various other industrial processes or their production as an important product on their own merits if direct uses can be found for the material thus produced. Another form of by-product research is concerned with the study and analysis of products that are already being manufactured in the plant as a by-product of the main function of the company. These products are either wasted entirely and eliminated by expensive waste-disposal systems, or are packaged and sold for some minor use at a price that barely covers the cost of the packaging

1. See page 100

materials. Many chemical industries have made millions of dollars by turning this type of by-product to use, similar to the usage of all parts of the animals in the meat-packing industry, a fact that has saved it from operating in the red.

Although the problem of management - labor relations is usually discussed in terms of wages, hours, and working conditions, management has a direct responsibility to labor in supporting the research of new products, products that have started completely new industries and employed thousands of workers. This is especially true in the field of the chemical and process industries where new products in the form of plastics, synthetic fibers, and many other chemicals are being placed on the market continually. Thus, by its support and guidance of new research ideas, management has given labor an entirely new source of employment. The chemical industry is reputably that with the largest value of assets per worker and it is due to the production studies of research laboratories that this has been made possible, and given to the workers some of the highest wage rates in all industry and employee relations which stand out as an example to most other industries in America.

The past few years have heard recurring cries to the effect that the country's natural resources are being consumed too fast. The research laboratory in the chemical industry has done much to prevent this occurrence or at least postpone the time when these resources will no longer be here.

This has been achieved in part by research on wood preservatives that have made it more valuable to the construction industry, after suitable treatment, than it was before and thus has tapered off the demand for fresh cut wood; by research on the methods of manufacturing synthetic fertilizers to take the place of that which has been removed from the

This has been achieved in part by research on wood preservatives that have made it more valuable to the construction industry, after suitable treatment, than it was before and thus has tapered off the demand for fresh cut wood; by research on the methods of manufacturing synthetic fertilizers to take the place of that which has been removed from the soil; and by many similar projects in the field of the fuels, i.e., coal, oil, and gas. Not only have substitutes been found for very many natural resources but at the present time every part of nature's contribution to mankind is utilized for the latter's benefit, as witness the press-wood industry(Masonite), and the manufacture of chemicals from the saw dust left-overs in the saw mills, especially in the Pacific northwest. In this and many other ways research is protecting the raw materials from which management hopes to continue to furnish the consuming public with products for many years to come. If this does not preclude a very concentrated effort on the part of management to support and understand the purpose of research, it has lost a large part of its initiative and foresight.

The last phase of research to be covered within the following chapters, and one that has only existed for the past few years, is the conversion of war research. By this is meant the research entailed in converting the discoveries of the war and for the war effort into useful and practical applications for American industry and the consumer.

Much research was done under the pressure of war that would have taken many years to have been discovered during a time of peace, and many of these discoveries have great utility in some other form which makes them adaptable to peace time uses and requirements. This unlimited source of information and ideas is being tapped at present for the benefit of the consumer in the form of a better way of life, and for the benefit of management in the form of the new products it is continually seeking to place on the market.

CHAPTER III

LOWER PRICES THROUGH TECHNOLOGY

The previous chapter gave a short summary of the remainder of this thesis, and in the discussion of the various types and purposes of research it mentioned the three stage process of aid to advertising in order to overcome sales resistance. In their correct order they are lower prices, better quality, and new products, and this chapter will be devoted to the elaboration of the first mentioned - lower prices.

The United States has always prided itself on the fact that its standard of living is the highest in the world. This can in no way be denied and one of the fundamental reasons for this situation is the fact that the American manufacturer has always made an attempt to lower the prices of his goods in order to bring them within the reach of a larger number of people. Whether this be in the production of automobiles, electricity or textile fabrics, the result has always been the same - greater consumption by an ever increasing number of consumers giving them greater earning capacity as workers and buying capacity as consumers. This in itself has helped raise the standard of living and bring to the American people some articles which elsewhere are considered a luxury. This story of lowered prices can well be illustrated by following the course of one industry, that of the synthetic cellulose textile fiber, rayon, in its various evolutions, expansions, and improvements during the forty years that it has been in existance in the United States. Here, therefore, as an example of the American philosophy of bringing goods within the reach of everyone, is the story of rayon.

A. Rayon - History and Developement[1]

As a commercial textile fiber rayon has only been produced in this country since 1911 at which time the American Viscose Corporation opened up its first plant at Marcus Hook, Pennsylvania. Due to the fact that this Corporation has been intimately connected with every advance made in the field of rayon technology till the present time, its story is being used as a basis for the story of rayon as it concerns the United States.

The desire for a man-made fiber which he could control and produce as he pleased was first put into words three hundred years ago in the "Micrographia" of Robert Hooke, an English naturalist. In his diary in 1664 Hooke wrote:

> And I have thought there might be a way found to make an artificial glutinous composition much resembling, if not full as good, nay better, than any existing fiber. This hint may, I hope, give some ingenous, inquisitive person an occasion for making some trials.

Almost a hundred years later, Rene de Reamur, a French scientist, while studying insects and the fibers they make in spinning webs or cocoons, also came to the conclusion that man could make a fiber out of gum or resin. This was

1. American Viscose Corporation Pamphlets (See Bibliography)

in 1742, but these men wrote before their time. Chemistry was not as yet far enough advanced to make their dreams realities. The man made fiber which is known today as rayon had to wait a hundred more years before science was ready with the techniques of production.

There had been some research on artificial fibers since the middle of the nineteenth century, but it had not resulted in conspicuous success until the search was stimulated by the need for carbonized filaments for Edison's great invention, the electric lamp.

As early as 1855 the first patent for making artificial fiber had been granted to Audemars, a Swiss chemist. From observing insects, he knew that liquid cellulose was the material they used in spinning their cocoons. He treated the inner bark of the mulberry tree with nitric acid and sulphuric acid to produce cellulose nitrate (which had been known since 1846 and is still used as guncotton in high explosives). This he dissolved in alcohol and ether. However, instead of forcing the liquid cellulose through fine holes as insects do, Audemars tried to form filaments by dipping needles into the solution and drawing them out into a thread. There was a great many difficulties in the way of this procedure and Audemars' process was not successful in producing a fiber of any commercial value.

After the invention of the electric light a search was instituted for a cellulose fiber to be carbonized into filaments. Among those who led the hunt was Sir Joseph W. Swan to whom goes the honor or producing in 1880 the first man-made fiber.

Swan began where Audemars left off. He, too, prepared a solution of cellulose nitrate, but instead of using needles as Audemars had done he had the ingenious idea of forcing the solution through tiny holes into a hardening bath to produce a fiber or yarn. He succeeded in making a long, unbroken thread and thus had invented the first practical method of spinning out a fiber - using the very first spinneret, the forerunner of the spinneret still used today. After treating the fiber thus produced with ammonium sulphide to remove the nitrate it was ready to be carbonized to form filaments. Swan's main interest, however, was in lamps and he did not exploit the textile feature of the new fiber he had produced.

The man who first produced this new yarn on a commercial scale and became "the father of the rayon industry" was Count Hilaire de Chardonnet of France. Chardonnet became interested in making artificial fibers as a student of the great scientist Pasteur, and under his training he approached the problem in a systematic manner. He worked almost twenty nine years to develop his process, drawing on the knowledge accumulated by other scientists of three centuries. He obtained his first patent in 1884 based on the work of Audemars and Swan, and five years later was exhibiting fabrics of chemically treated yarn in Paris. By 1891 he had built a plant for the regular production of yarn by the cellulose nitrate process, and finally after two hundred years an idea had become an industry.

Scientists other than Swan and Chardonnet were working on the problem of man-made fiber. One of the results of their research was the use of a copper ammonium solution for dissolving cellulose. Like the nitro-cellulose method this process, although discovered by Schweitzer in 1857, languished until the need for electric lamp filaments became imperative. By 1900 a succession of experiments by Weston, L. B. Despaissis, Fremary Urban, and Bronnert had made the cuprammonium process a commercial success.

The most widely used commercial method for the production of rayon was discovered by two English chemists, Charles F. Cross and E. J. Bevan. Working together they discovered that cellulose, when treated with disulphide of carbon in the presence of caustic soda, was converted into a golden yellow plastic compound which was soluble in water. A solution of this plastic was of such viscosity that the name "viscose" was given to it. These two men were the founders of the Viscose Developement Company which almost immediately bagan to make use of the molding properties of their invention. Soon viscose was being used in many different forms and ways. In solution it was a finish for linens, curtain fabrics and paper. As a solid it formed door handles, doll heads and valve wheels. But its real future was in the field of textiles.

Before viscose's promise as a new textile yarn could be realized, methods of manufacturing it had to be worked out. Ageing of the solution was found to produce better yarn. The spinning box was invented from the original needle used by Sir Joseph Swan. Only then did investment capital take up this new potential giant among textile fibers. As a result, production of rayon on a commercial scale by the viscose method spread rapidly, leaped the Atlantic to the United States where it flourished. Today only one other method is widely used in the United States for making rayon and the developement of that is given below.

In 1894, two years after they discovered the viscose process, Cross and Bevan secured a patent for the making of filaments of cellulose acetate. Their process entailed the steeping of cellulose in acetic acid and acetic anhydride to form cellulose acetate. This formed a thick, water-white liquid which when hydrolized becomes soluble in acetone. It was then precipitated in cold water as fine flakes, although when dehydrated and dissolved in acetone, it produced a liquid which coagulated in an acid bath.

The first successful textile application of this method was made in the United States. Dr. Arthur D. Little of Boston, who had been kept informed of the English experiments by Cross and Bevan, prepared cellulose acetate in films of considerable thickness. In partnership with Dr. William H. Walker and Harry S. Mork, Dr. Little was soon using the new cellulose compound for electrical wire insulation. In 1902 this group was granted a patent for spinning of textile yarn. This was the first patent on a manufactured fiber in the United States, and led to the world's first successful manufacture of acetate rayon.

In 1914 a system of air coagulation of the acetate solution was developed, and the acetate method was well on its way as an integral part of the rayon industry.

The first company formed in the United States to use the Cross-Bevan process of making yarns from viscose was the American Viscose Company, founded in 1893, and in no way connected with the present American Viscose Corporation. It was formed by the before mentioned Dr. Little, but confined itself to solution sheets and molded forms of viscose and did not attempt to spin filaments from the new material. Lack of definite commercial objectives led to the abandonment of the venture.

The second company was the Cellulose Products Company, formed in 1900 by D. C. Spruance of Philadelphia and Willard Saulsbury of Wilmington, with Dr. Little as chemical director. The organization devoted most of its efforts to films, solids, sizing and viscose printing of textiles, but it did make some attempts to spin yarn. Within a year the Company had exhausted its funds and the backers decided to await the developement of the process abroad before continuing operations.

Another enterprise, the General Artificial Silk Mills, was formed in 1901 and managed to produce several hundred pounds of yarn a day but the yarn was of such uneven quality that the organization was disbanded.

Meantime the British had been successful with their attempts to spin rayon yarn. Some of their product was imported into the United States where it found a ready market as material for braids, millinery trimming, hosiery, and for decorative effects in woolen goods.

In 1910, Samuel Salvage, a young English yarn merchant who had been in the United States for some years, saw that the time was ripe to begin full scale production of rayon in this country. There was a waiting market and the necessary techniques had been developed. Salvage persuaded the English textile firm of Samuel Courtauld and Company to form the American Viscose Company, now known as the American Viscose Corporation, and to build a plant here in the United States. This plant was to be the first commercial success in the production of rayon in the United States.

A tract of land in Marcus Hook, Pennsylvania, was the sight for the first plant of the new company, and although the townspeople were skeptical of its prospects, recalling the failure of similar projects, they found that the founders had planned well. In its first full year after construction, the Company turned out 362,544 pounds of yarn, a sensational output at that time. But this was only the beginning, and soon the infant industry was turning out millions of pounds of yarn in an effort to keep pace with the demand for its product.

For the first ten years, the Company pioneered alone in the establishment of the new fiber in the textile industry of the United States. This meant not only constant research and improvement in manufacturing the yarn, but also the adaption of knitting, weaving, and processing machinery to the use of rayon. Textile mills and machinery concerns with a vision of the future possibilities of the new fiber and with patience for its early faults and difficulties, developed winding machines, looms, knitting machines and dyeing processes, until their products became increasingly acceptable and attractive to the public.

After 1920 other companies entered the industry. Within five years there were eight and in 1935, the number had reached eighteen. Today there are fifteen producers in the field, with the American Viscose Corporation producing approximately one-third of the total amount of rayon manufactured in this country. The next seven companies in the order of their poundage output are Celanese, du Pont, Eastman Kodak, Industrial Rayon, American Enka, North American Rayon, and American Bemberg.

By 1924 rayon had made a distinct place for itself. It had properties and uses different from those of other fibers and produced fabrics that could not be produced in any other way. The old term "artificial silk" was no longer adequate and it was generally recognized that a new name was needed. The National Retail Dry Goods Association appointed a committee to select an appropriate name and chose the word "rayon".

The early use of rayon was limited to bright showy fabrics because it was produced only in a high luster. In 1926 after years of painstaking research the American Viscose Corporation produced the first dull viscose yarn and immediately new fields were open to rayon. Several methods for producing dull rayon are now used and the result is a variety of degrees of luster ranging from satins through every type of surface brilliance to the dull-finished broadcloths and georgettes.

Rayon yarn had been steadily improved by the producers until it could pass perfectly through the various machine processes and produce fabrics with durability as well as beauty. In 1927 another great improvement was made with the discovery that viscose rayon could be given a high twist and made into crepe yarns. This innovation opened up the large field of crepe fabrics to the new fiber.

In the same year rayon crepes first made their appearance, high-tenacity or high-stength rayon yarns were introduced. Their manufacture was made possible to a large extent by a special method of spinning developed by the American Viscose Corporation. In this method, the rayon yarn is stretched during spinning, resulting in a very marked increase in its strength, extending rayon's field of usefulness and giving striking proof of its versatility and serviceability. These higher strength yarns have made possible the creation of entirely new fabrics, as well as improvement in quality of existing fabrics.

Ordinarily rayon is produced as a continuous filament, but it may also be produced in fibers of short lengths. Until rayon was manufactured in these shorter lengths it could not be used for a whole range of woolen and worsted-type fabrics such as coverts, gabardines, flannels and tweeds. Production of rayon staple in this country commenced early in the thirties. Soon both viscose and acetate staple were available in a wide range of lusters, filament sizes and staple lengths, making it possible to weave rayon into fabrics of an extraordinary diversified usefulness. Rayon staple is manufactured in the same way as filament rayon except the filaments, after they leave the spinneret, are cut to definite lengths needed for different types of cloth.

In 1936 when tire manufacturers were looking for a cord material which could withstand the punishment of service in tires, research workers of the American Viscose Corporation contributed materially to developement of a special type of rayon fiber for the purpose. Tires made from this fiber have proved to be better able to withstand shock and resist blowouts. Since they run cooler, the rubber and tire deterioration is minimized and the tires last longer. Rayon cords make it possiblé to use less rubber in the tire wall at the same time creating a stronger, and lighter-weight, tire. It has been estimated that for every 1,000 pounds of extra strength rayon yarn used, there is a saving of 670 pounds of rubber, which, needless to say, served this country well during the war years and the resulting rubber shortage.

This was the last of the major process changes and fields for the application of rayon, and throughout the developement of this novel fiber, as was shown in the above history, the field of application was widening as more and more consumers and industries found that the properties of rayon suited their particular need. It would, therefore, be well at this point to elaborate on the research that has gone into this product as demonstrated by the American Viscose Corporation.

The American Viscose Corporation carries on four closely inter-related research programs. The first is product research, which concerns itself with the developement of better fibers and newer and better methods of production. The Standards Department, a division of this program, checks on the entire output of the Corporation plants, making sure that all products meet uniform standards of quality and performance.

The second reséarch department concerns itself with fabric developement, working with all available fibers, formulating them into new yarns and fabrics that utilize the unique characteristics of rayon. Building the structure or fabric from the Fabric Developement Department's designs is one of the functions of the Textile Research Department which is the third of the four-pronged research program.

The Textile Research Department is the only organization of its kind in the world. Its work is primarily research on new developements; that is, new techniques, new machinery, new fabrics, new fibers for new uses, and new uses for existing fibers. Also it constantly checks the Company's products for direct information on how the stock performs as the customers use it. It serves as a training school for key men in the Company, and as an authoritative source of information for thc entire industry. It performs a direct service for users of rayon by helping them in the solution of their production problems. To do this work, the Department is equipped with commercial size machinery for practically every operation in the textile industry. Here under one roof are the elements of six or more full sized mills. One for cotton system spinning, one for warping and weaving, one for knitting and one for dyeing and finishing.

The fourth and by no means least of the research departments is that concerned with the developement of finishes. This department provides technical assistance in the fields of dyeing, finishing, and printing. It also maintains an extensive research program in the interest of developing improved test methods for rayon fabrics.

B. Rayon - Stabilizing Influence in the Textile Industry[1]

The history and develppement of the rayon industry in this country has shown that through extensive research programs the field of application of this relatively new fiber has continuously been expanded. This same research program has not only brought rayon in its many forms and uses into the hands of thousands of the consumers in this country but has also managed to produce a textile fiber which, because of its relative price stability in contrast to the price fluctuations of the natural fibers, has immeasurably strengthened the textile industry by minimizing the factor of inventory risk. Not only has this price been relatively stable, but during the greater part of its forty year history in the United States it has been steadily decreasing. During and since the war the price of raw materials and labor has increased to such an extent that there was no way of avoiding having these increased costs reflected in the price of rayon. However, even this price increase has been considerably less, proportionately, than price increases in the other textile fibers such as cotton and wool.

The tabulation of monthly averages in cents per pound of the major textile fibers as listed on the following page tells its own story. However, the enormous increase

1. American Viscose Corporation pamphlets; Memorandum on the Rayon Industry by Morgan Stanley and Company.

TABLE I
COTTON, RAYON, WOOL AND SILK PRICES

MONTHLY AVERAGES IN CENTS PER POUND
(Selected Years)

Year	Cotton Yarn Combed 30/1's	Viscose Filament Yarn 150 Den.	Viscose Staple Fiber	Raw Wool	Raw Silk
1914	N.A.	195	(a)	61	369
1920	N.A.	460	(a)	166	908
1925	N.A.	205	(a)	139	657
1930	N.A.	106	60	76	341
1932	N.A.	66	46	47	156
1935	40.2	57	34	75	163
1936	37.3	57	31	92	176
1937	40.4	62	28	102	186
1938	31.1	52	25	70	169
1939	32.3	52	25	83	271
1940	34.1	53	25	96	277
1941	42.7	54	25	109	294
1942	48.7	55	25	119	(b)
1943	49.0	55	24	118	(b)
1944	52.1	55	24	119	(b)
1945	57.8	55	25	118	(b)
1946	68.8	56	25	103	679
1947	88.5	67	32	122	455
1948	95.3	75	36	159	260
1949c	78.2	74	36	171	300

N.A. Not available
(a) Not as yet produced
(b) No figures available during the war.
(c) Average prices for first nine months. Further declines in price occured towards the end of the year.

Source: Memorandum on the Rayon Industry by Morgan Stanley and Company in price between 1914 and 1920 requires an explanation. The patents that were originally taken out in the United States for the production of rayon by the Cross-Bevan method, as first discovered in England, were going to expire in 1920 and it was therefore up to the American Viscose Corporation, the only producer till that time, to take advantage of its monopoly, so to speak, while it could. And this they did, with a vengeance, charging prices for rayon that were as high as the market could possibly bear. This is illustrated by the fact that although the price of producing a pound of rayon yarn fell from $1.10 in 1911 to $0.60 in 1920, the cost of the yarn on the market rose from $1.85 to $4.93 during the same period of time. (The above prices are minimum and maximum for their respective years.)

During the period of greatest developement in the rayon fibers, between 1920 and 1940, the price of the product declined steadily, and, due to the instability in the price of natural fibers, the various rayon products were well ahead in the competition for the market by the end of the war. This effect was accentuated by the extreme rise in the price of the natural fibers by the end of 1948 which may be illustrated by the following example: While viscose filament yarn (which makes up about 50% of all rayon produced) increased in price to a maximum of 44% over its price of 52¢ in 1939, cotton prices went up nearly 200% rising from 32.3¢ in 1939 to 95.3¢ in 1948. What this variation in price must do to the textile industry can well be imagined when one considers that wool and cotton are bought by judicious hedging and that a considerable amount of speculative buying enters into the picture. In this analysis and table the acetate fiber and staple are not included as their price varies little from that of viscose fibers and the textile field is shared about equally between the two types of rayon.

The table of total textile consumption in the United States on the following page demonstrates clearly the way that rayon has forced itself into the fiber field in this country during the past twenty years. Although the total consumption of textile fibers in the United States has not varied by more than seven percent to either side of the average within the last ten years, that portion of this comparatively stable market that has been held by rayon has been nearly doubled. From a consumption of 591.8 million pounds in 1941 or 9.1% of total textile fiber consumption in that year, rayon has increased to 17.8% of the total fiber consumed with 1,149.4 million pounds in 1948. A similar situation made a highly favorable impression in comparison to the trend of business in general during the depression years, where it is reported that the rayon industry in the years 1932 and 1938 increased production as compared with 1929 by 11% and 136% respectively. Up to the middle of the war, when increases in rayon production began to taper off, the rayon industry had the enviable reputation of having doubled its

TABLE 2
TOTAL TEXTILE FIBER CONSUMPTION IN THE UNITED STATES

IN MILLIONS OF POUNDS
(Selected Years)

	Cotton		Chemical Fibers Rayon		Chemical Fibers All Others		Wool		Silk		Five Fiber Total
Year	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.
1926	3,214.8	87.3	60.6	1.6	-	-	342.7	9.3	65.6	1.8	3,683.7
1929	3,422.7	85.5	133.4	3.3	-	-	368.1	9.2	81.0	2.0	4,005.2
1932	2,463.3	84.4	155.3	5.3	-	-	230.1	7.9	70.5	2.4	2,919.2
1936	3,470.0	81.5	322.4	7.6	-	-	406.1	0.5	57.8	1.1	4,256.5
1940	3,953.6	80.9	482.0	9.9	5.0	0.1	407.9	8.4	35.8	0.7	4,884.3
1941	5,187.3	80.3	591.8	9.1	13.0	0.2	648.0	10.0	23.4	0.4	6,463.5
1942	5,636.7	81.6	620.8	9.0	26.0	0.5	616.2	8.9	5.0	0.1	6,904.7
1943	5,269.0	79.8	656.1	9.9	39.0	0.6	636.2	9.7	1.4	-	6,601.7
1944	4,792.4	77.7	704.8	11.4	49.0	0.8	622.8	10.1	0.6	-	6,169.6
1945	4,511.3	75.4	769.9	12.9	52.0	0.9	645.1	10.8	0.5	-	5,978.8
1946	4,906.6	74.4	875.5	13.3	56.0	0.8	748.3	11.4	6.5	0.1	6,592.9
1947	4,763.5	73.1	987.7	15.2	50.0	0.8	708.3	10.9	2.0	-	6,511.7
1948	4,540.5	70.1	1149.4	17.8	74.0	1.1	704.7	10.9	7.4	0,1	6,476.0
1949 a	1,902.8	72.8	419.6	16.0	40.0	1.5	249.8	9.6	2.2	0.1	2,614.4

a First six months

Source: Memorandum on the Rayon Industry by Morgan Stanley and Company production every five years since 1925, and the reason for this can be found in the large expenditures of the industry in research to produce better processes and to extend the fields of application of its product.

This survey of prices and consumption has shown how the extensive research programs carried out by one industry - rayon - have completely altered the complexion of a number of related industries. In this case the industries to be affected the most are those of textile manufacture and the manufacture of tires. In the textile industry the major effect has been one of stabilization, although the introduction of rayon as a new textile fiber in itself, and in combination with other fibers, has placed on the market numerous products that are immeasurable in their affect on the financial position of the textile industry but have nevertheless given it a much needed boost. The use of rayon in women's clothing has brought the luxury or silk type dress to the general public, and due to the savings in cost women today tend to buy several rayon dresses annually where they formerly bought only one silk dress. The same may be said of the rayon being inserted in men's suitings which will give them the feel and effect of wool while at the same time reducing their price to make them available to a larger number of consumers than was possible at the exceptionally high prices of pure wool. The use of rayon in tires has not only greatly reduced their chance of blowouts, increased their life and general stability under adverse conditions, but has also made a considerable dent in their price which makes them more attractive to the car owner.

C. Price Reductions in Other Industries

As the previous analysis concerned itself with a man-made fiber it is well at this point to give the comparative prices of another fiber, nylon, which was actually the first synthetic fiber made. Nylon was introduced to the public as a result of the pilot plant operation of a process as developed by the du Pont Company in 1938, the result of an extensive research program on synthetic polymers. Since that time its properties have been considerably improved and the fields of application have been developed to an extent that it has met with universal acceptance as an outstanding product, and is being discussed in greater detail in the capacity of a substitute product in the chapter that follows.

Nylon was first shown to the American public with considerable fanfare in 1938 but at that time the price of the product was considerably higher than the industries using it could afford, as it was only being produced in pilot plant quantities. Although no one could refute the exceptional properties of this new fiber there was never an absolute need for nylon, as other fibers fulfilled their various purposes satisfactorily for their users, and, although these other fibers might not last as long, they were considerably cheaper. Thus it was imperative that the price of nylon should be reduced in order to make it available to a wider market of consumers who would use it in preference to the other fibers not only because of nylon's superior qualities, but also because using nylon would save them money in the long run. The research department was thus called upon to improve the manufacturing process being utilized in the pilot plant in order that the final cost to the consumer would be reduced, this study being carried on at the same time as that being conducted in order to find wider and newer fields of application for the product. Although the reduction in the price of rayon, as mentioned in the previous portion of this chapter, was in part due to intra-industry competition due to the fact that there are at least five major producers competing for the market, this is not the case with nylon. Du Pont is still at the present time the only producer of nylon filament and plastics in this country, its manufacturing methods being protected by numerous patents. However, it does not enter the field of competition in consumer products as all of its production is sold to intermediate manufacturers who produce the goods for the consumer and industrial markets and thereby make the competition not between the source of the raw material, nylon filament or plastic, but between manufacturing brand names.

The price schedule for nylon since it was first produced in a full-scale plant in 1940 is given on the next page. It shows a steady decline in the price of nylon all

TABLE 3
PRICE HISTORIES OF TWO NYLON YARNS

SINCE PRODUCTION STARTED IN 1940

Price in Dollars per Pound

Date		30 denier 10 filament	40 denier 13 filament
January	1940	4.27	3.52
October 28	1940	3.95	3.27
June 16	1941	3.65	3.10
June 18	1941 (military use)	3.04	2.58
September 1	1945	2.75	2.25
February 17	1947	2.55	2.15
September 10	1948	2.70	2.25

Source: Letter from J. M. Gladden, Nylon Division, E. I. Du Pont De Nemours and Company, of December 15, 1949 the way through and after the war, until in 1948, when because of rising labor and handling costs, a raise in price was necessary. This reduction in price has been one of nylon's greatest selling points, as, in its downward trend, it was continually picking up consumers who were finding that the additional properties of nylon were well worth paying for especially if the price was within their range of expenditure for the article that nylon was substituting for.

A fine example of the reduction of prices by systematic research is taken from the petroleum industry, which, within the last twenty years has become the greatest source of intermediates in this country. (An intermediate is the compound that is formed between the initial material and the final product when referring to the chemical industry.) The use of petroleum as an intermediate has come about mainly due to the fact that it is a low cost source of a multitude of organic chemicals which are the raw materials for other processes, and which have been produced by processes developed by the intensive research programs of the larger companies in the oil industry, such as Standard Oil Company, (N. J.), Shell and Atlantic. Only these large, completely integrated, companies have the finances required to back the enormous research projects that have resulted in the developement of petroleum as a primary intermediate. The products and processes resulting from this research have made possible cheaper raw materials for other manufacturers and have largely replaced others produced from different basic raw materials both because of advantageous prices and properties.

The most important product of the petrolem industry in so far as the average consumer is concerned is gasoline, which has declined in price from 30¢ per gallon in 1920 to less than 15¢ per gallon at the present time (1950), exclusive of taxes. At the same time it should be realized that the quality of the gasoline has improved considerably, the octane rating rising from 79.7 in 1945 to one of 86.1 in 1948 for premium motor fuels. The rise over the same period for regular-grade gasoline was from 69.7 tO 75.2 motor octane rating, and this in only three years. This increase in octane ratings of gasolines was called for largely by the increased requirements of the new automobile motors which worked on a compression ratio of 7.5 to 1 in comparison to the pre-war cars that had a 6.5 to 1 ratio. The percentage gain in economy over the 6.5 to 1 compression ratio is considerable and will be largely reflected in a lower gasoline consumption per distance travelled, another reduction in cost to the consumer.[1]

Similar results have been obtained in a large number of petrochemicals, which, due to the results of the research departments in the field of production processes, have been produced at prices that are lower and in quantities that are larger than processes that produced the same final product with other materials than petroleum as raw material.

1. Pamphlets of Standard Oil Company (N.J.), and Universal Oil Products Company (See Bibliography)

Into this category fall such chemicals as glycerene and toluene whose production will be discussed in greater detail in the next chapter.

A short summary of some other products of the chemical and process industries that have had their prices slashed over a period of years is given here in order to show that price reductions are not a monopoly of the larger industries. Aspirin, the most used of all medicines and product of a large number of manufacturers, has had its price reduced by 86% between 1924 and 1945. Cellophane, of which du Pont produces 75% of the American consumption, has fallen in price from $2.65 per pound in 1924, the year in which it was first manufactured in this country, to 33¢ per pound in 1945, although since then rising prices have raised its price to 45¢ per pound. Chile, which had a monopoly on the world's iodine supply a number of years ago, charged the exorbitant rate of $4.00 per pound until such time as processes were developed in the United States to recover iodine from oil-well brines which reduced the price of this very useful chemical to $1.75 per pound this year. In the ten years before 1945, the price of hydrogen gas fell a total of 80%. All this shows that products that have had a certain amount of research conducted on their production methods, such as cellophane and iodine in particular, can reflect this work in lowered prices and therefore a greater field of utilization.[1]

The three major industries that have been given as examples in this chapter are only a small segment of those that are reducing the prices of their products through technological developement, as is shown by the numerous other price reductions occurring in the industry mentioned in the previous paragraph. This has not only brought a larger number of consumers into the price range of the article but has also made possible the increase in production of these articles to such an extent that further production overheads could be spread more evenly and again reflected in a lowering in the price. Although this process cannot go on indefinitely, it can be seen that the reduction of prices in an industry as a result of research in the production processes has benefited that industry tremendously and will in time amply repay the money expended on that research.

1. Scientific American, January 1945.

CHAPTER IV

BETTER MATERIALS FOR THE EXPANDING MARKET

Competition as it exists in the field of manufacturing in America today has resulted in the producers attempting to place on the market ever better products in order to obtain a larger share of the consumer's spendings. Most manufacturers are spending large sums of money every year in an effort to either improve the functioning and quality of products already on the market or to substitute for them other products made from different materials or by a different process. Whatever the method used, the final result must not only take over the functions in which the previous product had been lacking, but must be an out and out improvement on that product in every one of its purposes and functions.

The chemical and process industries are no different in this regard from the other branches of manufacturing, and, as a matter of fact, have much more competition to deal with than most, as was explained in some detail in Chapter II. Unless a chemical company is alert and one step ahead of its competitors it may find that while it had a market for its goods one day, that market was lost to a more active competitor the next day. Competition is largely in the form of the research that is being placed at the disposal of the sales and advertising divisions of a company in order that they may take advantage of all the opportunities available to them.

Research to improve the quality of a product is less specific than that required to reduce production costs but it does have the problem of determining when the product has been improved enough and work on it should terminate. In addition to this, estimates as to the value or earnings from improvements in products are much less specific than estimates of cost reduction returns, and this in no little way hinders management from giving this phase of research free reign. The subsequent portions of this chapter indicate the various methods used by some of this country's larger companies in improving the products on the market, the methods of manufacturing them, and substituting other and better products for them.

A. Improving Production and Quality of Existing Products

The number of products that have been improved either in their production methods or the quality of the final product is almost limitless. An example of this met with every day is the automobile which has developed from a rather cumbersome means of transportation in the early twenties to one of comfort, beauty, and speed. The chemical and process industries, however, have by no means let this type of research pass them by. Considerable developement has gone into the manufacturing of automobile tires and their ultimate wearing capacity,[1] into the numerous products now made from petroleum, into the improvements in natural fibers (as

1. See page 60

discussed in Chapter VIII), and in the methods of production of many of the strategic chemicals and metals required in this country.

As mentioned in the previous chapter, petroleum has become the foremost intermediate for the further production of plastics, synthetic fibers, rubber, and chemicals. Through the efforts of the oil companies to find added uses for their bountiful raw material, and at the same time produce these chemicals at prices that are lower and in quality that is higher than those of other producers, they have developed a number of processes that have completely revolutionized the chemical industry. The most recent of these, and one that caused the greatest stir, is the production of glycerine from petroleum as developed by the Shell Development Company and being produced at the Shell Chemical Corporation's new $8 million plant at Houston, Texas.

1. Fluid Catalytic Cracking.[1]

Standard Oil Developement Company, an affiliate of Standard Oil of New Jersey, is one of the most progressive of all the chemical industries' research organizations, and through its efforts was largely responsible for numerous new chemicals and processes being developed during and for the war effort of the Allies. One of the foremost and strategically most important of these was the developement of a

1. Pamphlets of Standard Oil Developement Company (See Bibliography)

manufacturing process for 100 octane gasoline for the Air Force, and for obtaining the raw materials for the synthetic rubber industry, as produced by the fluid catalytic cracking process. In order to present, at one point in this thesis, a more intimate and detailed description of a major research program for the benefit of the reader, the developement of this cracking process by the Standard Oil Developement Company will be presented.

In 1937 a so-called "fixed bed" catalytic cracking process was introduced on a commercial scale by two of Standard Oil's competitors. Catalytic cracking produces a higher octane number gasoline than can be economically produced by thermal cracking which was the method generally used at the time for converting higher-boiling, or non-gasoline, petroleum fractions into gasoline.

Cracking is a chemical reaction involving the breakdown of larger molecules to smaller molecules. It has been described as "making little ones out of big ones." Thermal cracking uses heat alone to break down the big molecules. In catalytic cracking, however, a catalyst applied at the proper temperature is used to cause the molecular breakdown. Compared with thermal cracking, the effect of the catalyst is to direct the cracking reaction, so that the resulting materials will contain more branched-chain molecules such as isooctane and isobutane. Branched-chain molecules help give gasoline a higher octane number.

The gasoline market is very competitive both on the basis of quality and price. No oil company can long be at a disadvantage in quality and in manufacturing costs and hope to compete. At the time of the "fixed bed" developemɑnt, a number of oil companies had been carrying out work on various types of catalytic cracking.

For obtaining a given octane number of gasoline it is possible, through the use of a catalyst, to carry out what might be considered a less severe cracking operation. Much less gas is formed. In addition the catalytic process is entirely operable, whereas with conventional thermal methods used in 1937, high octane gasoline could not be obtained - at least not under conditions that could be considered operable - due to the formation of coke in the cracking equipment.

In the catalytic operation, while coke is deposited, it is deposited on the catalyst - where is has the effect of decreasing catalytic activity. This is not serious, because the catalyst can be regenerated, or freed from the coke by burning it off the catalyst by air.

There are two main methods in which a catalytic cracking operation can be carried out. In one, the so-called "fixed bed" process, the location of the catalyst remains fixed. Oil is fed to the vessel containing the catalyst for a period of time. Then the flow of oil is discontinued, and the vessel is blown with air to burn the coke off the catalyst. By using more than one vessel, the oil stream can be maintained continuously, and each vessel is alternated between a cracking and generation operation.

The other method involves moving the catalyst. In this type of operation the catalyst flows continuously into a cracking vessel, and then into a regeneration vessel where the coke is burned off, and then back to the cracking vessel. Oil to be cracked flows steadily to the cracking vessel. Air for regeneration flows steadily to the regeneration vessel. The conditions in each vessel are constant with time. The catalyst itself is alternately exposed to oil vapor for cracking and to air for regeneration.

The Standard Oil Developement Company began its work on catalytic cracking with a fixed bed type of cracking. After some work on this process it was evident that an operation involving cracking for a while, and then regeneration, in a single vessel, had many operating and mechanical disadvantages. It was decided to explore a more continuous type of catalytic cracking, where the catalyst would move from a cracking zone to a regeneration zone.

The first idea was to suspend a finely ground catalyst in oil vapor for the cracking operation, and then suspend the same catalyst in air for regeneration. Standard Oil's research staff were thinking at the time of a kind of dust system, which did not involve high concentrations of catalyst in the oil vapor or air. Small-scale laboratory and pilot plant work carried out in this method looked quite promising. There were, however, some disadvantages to the operation. They found that, in order to secure time for contact with the catalyst, either for cracking or regeneration in vessels of reasonable size, it was necessary to use a moderate-pressure operation.

A large pilot plant was erected to investigate further this dust type of operation. One of the features of this operation was the necessity, at some point in the system, to take the catalyst from one pressure zone to a higher pressure zone to overcome the friction drop through the system. In order to convey the catalyst from the zone of lower pressure to the zone of higher pressure, the pilot plant operators and research workers tried using a compression type of screw conveyor, similar to the compression screws that are used to introduce solids into pressure-conveying systems.

The initial operation of the large pilot plant was reasonably satisfactory. The capacity was not quite as high as had been expected from smaller pilot plant work, but nevertheless the operation looked promising. In fact, things were going along quite smoothly when the head of the department at Baton Rouge, where the large pilot plant work was being carried out, called the head office with bad news. He said they were experiencing trouble in circulating the catalyst through the unit, because the dust grains seemed to increase in size. Little balls of catalyst seemed to be forming.

This was not understandable. The superintendant was asked to continue the operation and try to discover just what did occur. He did and found that actually the catalyst was tending to build up into small spherical particles, considerably larger than the original catalyst. With this background, the Company dug further into the problem and found, to its surprise, that some makers of carbon black pellets use a type of screw conveyor to form carbon black powder into balls. Thus, by accident, they were using a similar process to make catalyst balls, which was not what they wanted.

The Standard Oil Developement Company then realized that they had a fundamental difficulty, and that it would not be feasible to use a compression screw to transfer catalyst from the low-pressure level of the regenerator to the high-pressure level of the cracking zone. Either a change in the method or a whole new process was required.

Sometime before this experience the Standard Oil Developement Company had become interested in the flow properties of finely divided powders suspended in gas. It was particularly interested in how fast these powders would move in an up-flowing gas stream, that is their slip velocity. Dr. W. K. Lewis at Massachusetts Institute of Technology was asked to make an investigation of the flow of powders. He discovered that if a gas stream and a powder flow continuously into a vessel, it is possible - with the proper conditions of velocity and rate of introduction of fresh powder - to build up a highly concentrated, turbulent bed of powder in the vessel. Furthermore - and this was most important - the powder in the vessel will be in a fluid condition, and will act much like water. In addition it was found that much higher gas velocities could be used than would be expected from entrainment considerations based on Stoke's law. This work showed the Company how to get adequate contact of oil vapor or air with the catalyst, in a reasonable volume of reaction space. It also eliminated the need for working at higher pressures. However, Standard Oil still had the problem of taking the catalyst from a low pressure zone to a higher pressure zone to overcome the friction drop in the catalyst circulating system.

Several methods were considered. One idea was to use lock hoppers but this proved too complicated. Then they conceived the idea of producing a hydrostatic head, by putting the catalyst in a standpipe and aerating it so that the desired increase in pressure would be generated by the fluid pressure of the catalyst itself. Those in the employ of the Company with experience in handling solids were afraid that the desired pressure build-up would not be obtained because of arching and also that the pressure would not be steady. These technicians decided, however, to go ahead and find out. They erected a standpipe more than 100 feet high, and provided a way to aerate the catalyst, and take it from the bottom of the standpipe and blow it to the top in a separate circulating line.

This system gave excellent pressure build-up, plus high catalyst densities in the standpipe. It was a very simple type of operation when proper aeration was used. There was no trouble with plugging and the pressure was steady.

This gave the tireless workers of the Standard Oil Developement Company the second part of the fluid catalytic cracking process. The name "fluid" was adopted because the catalyst powder was handled in such a way that it acted like a fluid. It is of interest to know that the use of standpipes allows circulation of large quantities of solids. For example the rate of catalyst circulation in a large fluid catalytic cracking plant may be the equivalent of over a boxcar of catalyst per minute.

The pilot plant was rapidly modified so that gas velocities could be adjusted to give a dense bed of catalyst in the reactor and regenerator, and standpipes could be used to generate pressure for transferring catalyst between reactor and regeneration zones. The pilot plant, when modified in this way, gave excellent results from the start. The feeling was evident that they had developed a simple process for carrying out catalytic cracking. The Standard Oil Developement Company immediately started modifying the designs of two commercial-scale catalytic cracking plants, which they planned to build.

About this time it became evident that there was to be a war, and that there would soon be urgent need for light hydrocarbons such as butylenes and isobutene for high octane aviation gasoline. These hydrocarbons were also required as intermediates for making the butadiene needed in synthetic rubber manufacture. Pilot plant work demonstrated that the fluid cracking process could be made to give high yields of the light hydrocarbons needed. Indeed, it appeared to be the best process available. As a result of their developement work a number of oil companies decided to install fluid catalytic cracking plants without waiting for a full-scale demonstration. In fact, thirty two units were in the course of construction before there was any commercial-scale demonstration of the fluid cracking process. At the same time alkylation plants to make 100 octane aviation gasoline components, and butadiene plants to convert butylenes into butadiene were being built. Their success would depend on the success of the fluid catalytic cracking. At the same time the rubber industry was building synthetic rubber plants, which would depend on the butadiene plants.

It was evident that a good bit of the success of the war, as well as the success of an investment of approximately one billion dollars depended on the successful operation of the commercial fluid catalytic cracking plants. The research staff was doing everything possible to expedite the pilot plant developement, and to obtain the necessary design data for the commercial units. All operating difficulties that could be thought of were investigated. Research groups pushed themselves to the limit to get out the information. The same is true of the engineers who designed the commercial plants.

When the first commercial unit went into operation at Baton Rouge the entire petroleum industry was holding its breath. As can well be imagined there was a great feeling of relief, and also a sense of accomplishment, when the first unit operated smoothly from the very beginning.

The fluidized solids method of contacting and handling mixtures of gases and solids developed in connection with the fluid catalytic cracking operation represented a new chemical engineering technique. It is felt that this technique will have applications in many other fields. One of these is discussed in some detail under the chapter heading "Complete Utilization of Materials" further along in this thesis, where the process is used to produce a wood cake that utilizes saw-dust waste. Another use of this technique is in the liquefaction of coal and shale as mentioned briefly in the chapter on "Research and the Natural Resources".

However, by far the most important application of the fluidized solids technique today is for the catalytic cracking of oil, its original purpose. Catalytic cracking offers very real advantages over the old thermal cracking technique, in that it provides a much higher octane gasoline, and in addition gives a higher yield of gasoline on the oil being cracked. This is very important at the present time due to the increased requirements in octane rating of the gasolines to satisfy the higher compression ratio of the newer automobile motors as described in the previous chapter. As an example, from a typical crude through catalytic cracking it is possible to produce the same volume of light products such as gasoline, kerosene and domestic heating oil from 16% less crude oil.

2. Synthetic Toluene.[1]

In some respects synthetic toluene came a close second to catalytic cracking in the research projects for the war effort, and was also a developement of the Standard Oil Developement Company.

The war brought on the need for large quantities of toluene for the explosive T.N.T. The demand was much larger than could be satisfied through coal tar operations, which had been the source of the toluene in the past. Just prior to the war the Standard Oil Developement Company in conjunction with M. W. Kellogg Company had studied a catalytic operation for converting certain constituents of petroleum into aromatics, the conversion being carried out with high yields. The Army approached the Developement Company to see if there were any new possibilities on the production of synthetic toluene. The newly developed catalytic operation

1. Pamphlets of Standard Oil Developement Company. (See Bibliography)

for production of aromatics was discussed with the Army, and its possibilities for making synthetic toluene were pointed out. The Army asked that a demonstration lot of synthetic toluene be made up to determine if the product was suitable for nitration. Using improvised equipment, and with separate parts of the operation being carried out at various locations, it was possible to produce two tank cars of nitration toluene, which were sent to the Army on August 8, 1940. Nitration of this material was entirely successful, and on October 21, 1940, the Army entered into a contract with the Humble Oil & Refining Company, an affiliate of the Jersey group, to erect a large synthetic toluene plant. This plant was completed in record time, and its first shipment went out just one year after the Army signed the construction contract.

At its peak, during the war, this plant produced about 5,000 barrels of synthetic toluene per day. This one plant supplied more than one-half the toluene that went into T.N.T. for the United States Armed Forces, and, together with other companies using Standard Oil's process or modifications of it, entirely met added war needs for toluene. The production of this plant was about four times that of the whole coal-tar industry which was the main source for toluene in the first World War. In addition, it produced about 2,600 barrels per day of xylenes, which had various war uses.

One of the most important phases of this operation in regard to research was the speed with which the complete process for the production of synthetic toluene from petroleum was set up. Although it no longer takes the accepted seven years for a product to grow from the test tube to the tank car stage, a study made by H. B. McClure of the Carbide & Carbon Chemicals Division of Union Carbide & Carbon Corporation resulted in the figure of five and a quarter years as the average developement time for seventeen products that had been placed on the market by his Company in the last two years. This shows little progress over previous developement times, and emphasizes the achievement of the Standard Oil Developement Company's research workers the more in bringing their synthesis of toluene to fruition in the space of approximately three years. This demonstrates, as few other examples can, that research in industry can give management sterling aid at little more than the proverbial "moment's notice".

Following the end of the war the synthetic toluene plant was purchased by Humble and is now turning out xylenes, toluene, and certain high boiling aromatics. Today it is the largest single producer of aromatics in the world. The hydroforming process that is being used represents a major step in converting the aromatics industry from a coal-tar base to a petroleum base. Large scale production of aromatics at a central location offers the further possibility of the economic isolation of many pure aromatic compounds that it has not been feasible to make with small production facilities at scattered locations.

However one of the greatest advantages to be derived from the conversion of the aromatics industry from a coal-tar to a petroleum base is the fact that the former has become a very unstable source of chemicals due to the vagaries of the coal industry. The large number of paralyzing coal strikes since the end of the war have made coal a poor chemical intermediate and a large number of industries are attempting to become independant of this raw material for that reason and also the fact that it is no longer as cheap an intermediate in price as it used to be. The production of aromatics from petroleum has therefore given management the opportunity to divest itself from the ever recurring problems brought about by John . Lewis and his striking coal miners.

3. Synthetic Glycerine.[1]

Since before 1937 the Shell Development Company has been engaged in the creation of a new chemical industry based on allyl compounds derived from petroleum hydrocarbons. This comprehensive program of basic research, process developement, product evaluation, and engineering design is materializing in an integrated series of chemical plants involving an investment approximating $12 million.

1. Chemical Engineering, October 1948

A major objective in this program was reached in September of 1948 with the completion of the world's first plant for the commercial production of synthetic glycerine. Thus there has been provided a primary industrial source for an essential chemical which for centuries has been available only as a by-product from the manufacture of soaps and fatty acids. This process was the result of research by Shell Developement Company and the plant was built in Houston, Texas, at an estimated cost of $8 million. Its capacity is approximately a fifth of the national prewar output of glycerine.

4. Automobile Tires.[1]

Having seen in some detail the methods used to improve the production processes of various products from petroleum it is of interest to mention a product that has been radically improved, both in its functioning and characteristics, by developement research in the chemical and process industries, in this case the rubber tire industry.

This product is the automobile tire, which, of all the numerous products that come to mind, has seen the most radical changes take place in its components. This tire now boasts three radical improvements over the one that was riding on the highways ten years ago. The first of these was the

1. Pamphlets of Standard Oil Developement Company and American Viscose Corporation; Chemical Engineering, October 1948, April and December 1949, February 1950; Chemical and Engineering News, June 13, 1949.

introduction of rayon cord into the body of the tires, as mentioned in the previous chapter. This textile carcass of the tire, and not the rubber around it, supports the load of the vehicle and its contents. It prevents the tire from growing excessively, ballooning out under high internal air pressure, or flattening out when sharp road obstructions are met. The rayon cord enables tire walls to be made thinner, using thinner cords or fewer plies. This enables the tire to run very much cooler, and, although the difference is seemingly small, heat is the major enemy of the life of the tire, cuts down mileage enormously and is the principle cause of tire failure. The difference of a few degrees is the difference between economy and waste, safety and hazard. The rayon cord, besides giving longer life and mileage, also increases the tire safety by having a 32% greater resistance to body breaks than the general average of other cords and thereby reduces blowouts and makes it possible to maintain heavier loads and higher speeds without sacrificing safety.

The introduction of two separate types of rubber during the war supplies the other improvements in the tire of today, although one of them was a further developement of the original process. One is the manufacture of the first general purpose synthetic rubber, known as GR-S (Government Rubber - Styrene), and the other is the production of Butyl rubber, which, although it is considerably less elastic than natural rubber, has the unique advantage over the latter in that it is about one-tenth as permeable to air. The GR-S being referred to here, however, is not that produced during the war to substitute for this country's natural rubber imports, but an improvement on this method, developed in 1943, which produces the synthetic rubber at a temperature of 41°F instead of at the usual temperature of 122°F, and therefore given the name of "cold" rubber. This reduction in temperature produces a rubber that is, for the first time, a real commercial threat to natural rubber because it results in automobile tires superior to those now made from the natural product, the tire industry being the greatest consumer of natural rubber in the world. When compounded with improved carbon black and used for tire treads, an increase of about 30% in mileage in obtained. Despite the additional cost of regrigeration the total cost of "cold" rubber is as low as standard GR-S because of cheaper materials used in the polymerization recipe and greater process efficiency, and it is likely that, as the manufacturing processes are ironed out, further decreases in cost will be effected.

Butyl rubber, again, was wholly a developement of the Standard Oil Developement Company which also bore the entire cost of research and developement. The final product of this research, as can be well imagined from its characteristics mentioned previously, was used to make superior inner tubes for tires. Butyl rubber inner tubes, today, are basically safer than those of natural rubber, have better tear resistance and require much less frequent addition of air. The properties of butyl rubber tubes are so exceptional that they are causing some of the butyl rubber plants, being operated by Esso Standard Oil Corporation under government contract, to shut down. What is happening is that butyl rubber tubes are lasting as long as or longer than the tire casings. Their better retention of air also increases the casing life, and with the prospects of cold rubber (GR-S) treads in the offing, a revolution is under way in the replacement tire and tube business. All this shows the tremendous improvements that have gone into the tire of today and the benefits the public will enjoy as a result of the research and developement in the rubber tire industry.

In order to obtain an idea as to how much money such developements cost the company that conducts them, here are a few figures. The Standard Oil Developement Company spent more than $9 million on fluid catalytic cracking - from the time research started until the operation of the first large plant. The research and developement cost of synthetic toluene was more than $2 million. This does not include the cost of the plant, which was built with Government capital. To date, for research and developement on Butyl rubber, Standard Oil has spent about $11 million. This again does not include any plant investment, since the Butyl rubber plants were financed by the Government.

The remarks made in the last paragraph of a speech given by E. V. Murphree, President of the Standard Oil Developement Company, in his acceptance of the 1950 Perkin Medal Award, given by the American Section of the Society of Chemical Industry, provide a good summary for this portion of the chapter:

> The developement of new or improved products, and new or improved techniques in our industry, provide for continuing high rates or employment. They increase our standard of living. Such developements are essential to our national defense, and are the life blood of our western civilization. The incentive for the financial risks involved is the expectation of profit from those which are successful. I hope we never see the day when, through restrictive legislation or other Government action, this expectation ceases to exist.[1]

B. Substituting Improved Products

This portion of the chapter will again lay considerable stress on the role that the synthetic fibers are playing in modern industry. Each, with its own specific properties and limitations, has made a place for itself among the numerous uses that industry has for products of that type, where they are replacing other fibers, cotton, hemp, rattan etc., whose growth or importation was restricted during the war and whose place they are still filling as well, if not better, than it was being done before. Although probably the most

1. Adventures in Applied Chemistry by E. V. Murphree

important of these fibers is nylon, this product only appears in the form of a fiber that can be woven into material or other similar products and for the benefit of a wider field the plastic, Saran, which not only appears in the form of a fiber but may also be molded, is given priority in this connection.

1. Saran[1]

During 1838, the French chemist, Regnault, in his studies encountered a strange new fluid which was later determined to be unsymmetrical dichloroethylene, now more commonly known as vinylidene chloride. From that time until the beginning of the last decade, this material has been in the literature only rarely.

In 1922, B. T. Brooks indicated that halogenated ethylenes other than vinyl chloride and vinyl bromide show a tendency toward polymerization. Staudinger and Feisst, reporting in 1930 on the polymerization of an apparently impure unsymmetrical dichloroethylene, indicated that the liquid polymerizes quickly in light or slowly when kept in the dark. This polymeric material is completely saturated, and its structure is represented by the long dichloroethylene chain. Feisst reported the polymer to be crystalline, as later confirmed by G. Natta and R. Rigamonti.

The developement of vinylidene chloride by the

1. Pamphlets of Dow Chemical Company. (See Bibliography)

Dow Chemical Company, the present producers of the product saran, began actively over twenty years ago. Research men investigated the material while working on chlorinated aliphatic compounds. Based on that original study, a thorough program on vinylidene chloride was instituted. As a direct result of that program, it was possible to produce the first vinylidene chloride polymers in a commercial way early in 1940.

One of the outstanding characteristics of Saran is its resistance to chemicals and solvents. At room temperature it is extremely resistant to all acids and to all common alkalies, except for concentrated ammonium hydroxide. Slight discoloration with little change in mechanical properties will occur when exposed to concentrated sulphuric acid or caustic over long periods. It is substantially unaffected by both aliphatic and aromatic hydrocarbons, alcohols, esters, ketones, and nitro-paraffins. It is swelled or softened only by oxygen bearing organic solvents such as cyclohexane and dioxane. This resistance to solvents and chemicals decreases with a rise in temperature.

A second important characteristic of Saran is its extremely low water absorption and vapor transmission. The basis polymers are odorless, tasteless, and non-toxic. Their high refractive index enhances their many color possibilities, while their toughness and abrasion resistance are of a high order, and the retention of these properties upon ageing insures excellent wearing qualities.

There are three major methods of producing Saran plastic products. In the form of solid plastics they are made both by extrusion and injection molding, while extrusion produced mono-filaments are woven into standard textile materials. Due to their exceptional properties as mentioned previously, the extruded Saran has been produced in some of the following forms: rods for making gaskets, valve seats, ball checks, medicinal pröbes; chemically resistant, flexible tubing and pipe; tape for wrapping joints; chemical conveyor belts; tape and strips for die cutting; and various items of wearing apparel.

Injection molding offers the second fabrication method for Saran. This method makes possible the production of intricate shapes having properties similar to those obtained by extrusion. Injection molded Saran played a considerable part in national defense. In many of its applications it was as a metal replacement and not as a thermoplastic. Comparative tests showed that, in many cases, Saran was the only material that would satisfy the industrial requirements for the replacement of such strategic materials as nickle, aluminum, stainless steel, and rubber in applications requiring chemical resistance. Some of these applications are listed here: a) Because of its solvent and abrasive resistance it replaced aluminum in spray-gun handles, where the practice of cleaning the equipment by washing in potent lacquer solvents does not effect Saran. b) It was used in valve seats because of freedom from channeling based on abrasion resistance, its seating qualities based on its resilience, and in some applications, its resistance to corrosive gases and liquors. In this application it replaced precision machined metal seats and imported horn seats. c) It replaced glass in hard usage where much breakage occured as an acid dipper because of its great acid resistance and toughness. d) In the rayon industry it has been used for moldings such as spinnerette couplings, gasket holders, filter parts, nozzle tips, rollers, and guides. Because of its inertness and stability to chemicals and solvents used in processing rayon, replacing special formulations of hard rubber. e) Molded pipe fittings for chemical, paper, rubber and plastic industries.

The above uses during the war were one of management's greatest worries, and, as the war progressed and more and more materials became of strategic importance, they were withdrawn from the market and users of that material had to supply substitute parts at a moments notice. Into this breach came Saran and not only did it completely satisfy all expectations but has been retained in a large number of these uses because in the first place it is usually cheaper than the metal it replaced and secondly actually did a better job. In this way Saran came to take its place in the ranks of major materials which started out as substitute products and developed into a standard product for those particular uses.

The third but by no means least important of these methods of fabrication for Saran is that of extrusion to produce monofilaments. Many uses of Saran monofilaments fall in fields formerly supplied by imported natural products, such as hemp, long fiber paper, rattan, reed, horsehair, Spanish silkworm gut, and linen. Most of these substitutions made during the war have been found to have permanent benefits and have kept their place in competition with the fabrics that are now again available.

Saran's extreme chemical resistance suits it for use in filter fabrics. Saran's high wet strength and its chemical and fungal resistance have directed its use to special ropes and cores for wire ropes. The general attractiveness and range of color possibilities fit this material for such apparel accessories as belts, suspenders, handbags, and shoes. Long life, ease of cleaning, abrasion resistance, and flexibility, as well as color possibilities, have attracted upholstery fabric applications to Saran. In subway transportation seating it showed no material wear, and appeared like new, after a hard year of service. Saran upholstery fabric is now being used in train and bus seats, as well as household furniture and automobile seat covers.

The latest addition to the field of application for Saran is that of screaning, using monofilaments. Saran screening already amounts to 20% of all the metal screening that is manufactured and due to the fact that it is resistant to the effects of salt air in coastal regions, and chemicals, it is being widely used in these surroundings. In addition to this it costs less than aluminum and bronze screening which are usually used under these conditions.

In its three major forms, Saran has found numerous applications for its exceptional properties. Largely due to these properties industry today is supplied with a product that requires much fewer replacements, costs less to install originally and gives better service than the products that were originally used for the purpose. Having entered the market as a substitute material for those that were required more urgently by the war, Saran has remained a substitute, but permanent, for those materials over which it had a number of advantages and which are now finding applications elsewhere. This shows that research has again produced a product that is of inestimable value to industry as a whole. A completely new field of products has been produced, new plants have been built employing more and more workmen, and through the same successive steps they have taken their place among the major new products of the industry in line with nylon, rayon and the plastics.

2. Nylon[1]

1. Pamphlets of Du Pont Company, Nylon Division (See Bibliography)

Nylon, which was discussed in Chapter III, emerged about twelve years ago as the unpremediated outcome of a program of fundamental research conducted in the Experimental Station laboratories of the Du Pont Company at Wilmington, Delaware. The purpose of the scientific study was simply to acquire knowledge of the mechanisms for making very large organic molecules, such as are built by nature as the structural materials of cotton, wood or silk. There was at the time no specific commercial objective. The fact that from the program came a whole range of new products providing new employment for labor and capital has often been cited as spectacular argument for industrial support of fundamental as well as applied research.

Many people are not aware that nylon has many other uses other than in stockings and brushes. Its first commercial use was in tooth- and hair-brush bristles. Then came its dramatic appearance in stockings, and its equally dramatic disappearance into wartime uses such as parachutes. But nylon actually is a tough plastic from which a great variety of articles may be made.

The name nylon does not refer to a single substance, but to a family of related substances. Nylons are chemically similar and have the common ability to be formed into textile fibers. At Du Pont's new Washington Works, near Parkersburg, W. Virginia, nylon is made in the form of filaments to be used, for example, in bristling brushes, and as plastics in the form of powders from which finished articles are molded by other manufacturers.

The properties of nylon yarn which make it an outstanding fabric are given here in order to enable the reader to evaluate its potentialities and better to understand why it is being used in such a variety of fields. Nylon yarn has a high tensile strength and is light in weight, being twice as strong and half as heavy as the same size of aluminum wire. Even when wet, nylon retains about 85% of its strength, although it dries very quickly as it absorbs little moisture. Partly due to this and the fact that it is a synthetic fiber makes it resistant to mold and other microorganisms and soil rot. Nylon's tensile strength and unusual abrasion-resistance, due to smooth filaments minimizing friction wear, combine to give it an outstanding toughness and ruggedness even in light-weight constructions. Nylon can be shaped or set under moist or dry heat, the setting providing excellent shrinkage control. In addition to this it can be repeatedly stretched or flexed without loss in elasticity of the fabric. The advantages it exhibits in the industrial fields are that it is resistant to alkalis and hydrocarbons, being highly resistant to soap solutions, oils, and petroleum. Its strength is little changed under any of these conditions or by long immersions in salt water. Nylon does not support the spread of flame and resistance to deterioration under heat makes possible long exposure to steam and dry heat at elevated temperatures.

Industrial uses of nylon textile fabrics are numerous and for the sake of brevity only the most important will be mentioned here. The consumer fabrics in the form of hosiery and other wearing apparel need not be mentioned here as they are only too well known to everyone. Nylon filter cloths serve unusually well in many industries especially for filtering alkali and neutral solutions. Diaphragms for a wide variety of uses are now being made of coated nylon fabrics. Its extremely high resistance to flex fatigue, heat, gasoline and chemicals are its chief contributions to diaphragms for carburetors, pumps, and gas measuring devices. In many of the industrial applications for rope, nylon has already proved itself. Among these are air-mail pick-up ropes, yacht ropes, tow ropes for gliders, mooring lines and rope belts for power transmission. Coated nylon fabrics are now specified for the inflatable boats up to 20-man capacity that are required equipment on all American planes, commercial and military, that fly over large areas of water. Nylon is being widely used as a fabric cover for steam presses due to the fact that it lasts three times longer than any other material, is not effected by starch, and does not turn brown with the steam and cause the clothes to stain. One of the foremost industrial uses is as an insulating wrap or covering for extremely fine instrument and armature wires, particularly where space is at a premium. Strength, light weight, uniformity, abrasion resistance, low moisture absorption and toughness all contribute functional value to this and other uses.

As a molded plastic and in the form of monofilaments there is a completely different range of uses a few of which are mentioned here. Nylon's great durability qualify it for more and more hard-working assignments in industry where it is at present being used as a hammer head for soft-impact hammers which avoid the marring of the material being worked. Wire coating and such articles as coilforms, Housewares, wristwatch straps, and bearings are made from nylon molding powders. In the form of the monofilament nylon has gone into brushes of almost all types - from brushes for the commercial scrubbing or rugs, or for use in dairies and breweries, or in vacuum cleaners, to soft cosmetic brushes for women and shaving brushes for men. A major developement in nylon monofilament came during the war due to the lack of imports of natural bristles from Asia, being the discovery of a way to manufacture tapered filament for paintbrushes. In lines closer to the average consumer nylon monofilament is used in tennis rackets, surgical sutures and fish lines.

There is no need at this time to write about the effect of nylon on both the textile industry as a whole or on Du Pont the parent firm. The profits being made from th production of this fiber are inestimable and so also are the dollar benefits to the industrial users of nylon fabrics, using them to replace other and inferior fabrics. The ultimate in consumer acceptance of this new fabric is achieved in an example of a hotel in Wilmington, Delaware, which has converted 100% to nylon fabrics for economy of wear and care. Included among its applications are ballroom draperies, upholstery on all the furniture in public and guest rooms, window and shower curtains, tablecloths, blankets and sheets, rugs, bedspreads and lampshades. And all this as the result of fundamental research on the formation of fibers by nature's insects.

3. Orlon.[1]

The latest fiber to enter the synthetic field to compete with those already existing is Du Pont's newest find, formerly called Fiber A, but now given the trade name of Orlon. Orlon is an acrylic fiber manufactured from polyacrylonitrile. A product of Du Pont research, it is now passing from the experimental stage of developement to commercial production. Construction of a plant is under way at Camden, South Carolina, and it is expected that continuous filament yarn will be available commercially late in the fall of 1950.

Ever since nylon had passed the developement stage and was being produced in commercial quantities Du Pont had

1. Pamphlets of Du Pont Company, Rayon Department. (See Bibliography)

been looking for a continuous filament, synthetic fiber having the warm, dry, luxurious texture and dimensional stability of silk in high humidities. They had also been searching for a staple which would have the exceptional bulking power, high thermal insulation and wrinkle recovery processed by wool. Still another objective was to develop a fiber with strong attributes which would allow Du Pont to make a contribution to the industrial and domestic fabric fields - a fiber which has extraordinary resistance to outdoor exposure, chemicals, microorganisms, and insects, along with high strength, low sensitivity to moisture, good heat resistance and high flex life.

Five years of searching market exploration, employing a large poundage of Orlon fiber produced by the pilot plant, convinced Du Pont that it was an industrial fiber of the first order. Not only this, Orlon continuous filament yarn is the most silk-like synthetic fiber, while the staple is the most wool-like synthetic fiber, known to man at the present time. It has a combination of properties which will give it a wide diversification of markets and cause it to be suitable for many purposes in which the rayons and nylon will not equal its performance. For one thing, Orlon's resistance to outdoor exposure is so good that Du Pont made the statement that it was the best fiber, natural or man-made, for outdoor use.

This single salient characteristic of Orlon will extend the frontiers of utility of industrial and domestic fabrics. However, if the other attributes of Orlon are pyramided along with its sunlight resistance - i.e., high dry and wet tensile strength, high resistance to stretching, high flex life, rapid drying, bonding to resins and rubbers, dimensional stability to heated gases and liquids, resistance to acids and acid fumes at high temperatures, resistance to insects, molds, mildew, and other microorganisms - then the broad utility and versatility of Orlon as an industrial and domestic yarn can be viewed in the proper perspective.

Since nylon has greater abrasion resistance, retains a greater percentage of its strength in air at higher temperatures, and has a much better resistance to alkalies than Orlon, it is apparant that Orlon will supplement, rather than compete with nylon in the industrial and domestic fabric fields.

With regard to outdoor resistance, Orlon stands in a class by itself. Tests have shown that, when the time of exposure is sufficient to cause all other fabrics to lose 100% of their strength, Orlon has retained 85% of its original strength; after one and a half years under the exposure of the elements Orlon had lost only 23% of its tensile strength.

Orlon acrylic fiber has good to excellent resistance to mineral acids, fair to good resistance to weak alkalies, and is not harmed by common solvents, oils, greases, neutral salts, and some acid salts. This chemical inertness of Orlon, especially to mineral acids, indicates that it is a good candidate for many uses in the chemical industry. In addition to this it can be used at higher temperatures in acidic liquid and gaseous mediums than many other fibers. Due to this it will solve many a problem in the filtration of industrial and nuisance dusts by bag filtration where the materials used previously could not stand temperatures over 235°F. Research in this field has shown that Orlon can be used in the neighbourhood of 280°F. for various kinds of filtration without unreasonable shrinkage of the material.

A real need for fabrics which are more suitable for protective work clothing exists. Both the employer and employee in the chemical process industries, rayon plants, garages, and gasoline stations are seeking acid resistant fabrics which will give better protection and safety to the worker. Fabrics are desired which will not require father to hand the garment down to his son after heat shrinkage has resulted from contact with boilers, steam pipes, and radiators. In all these requirements it has been found that Orlon can fill the need.

To sum up, Orlon's industrial fabric applications are based on some exceptional properties which are listed here and which can be expected to make it a strong contributor to the fields of application which follow, both on the basis of unit function per dollar cost and more satisfactory performance. Orlon has high strength, outdoor durability, high flex life, acid resistance, resistance to microorganisms, low sensitivity to moisture, heat resistance, bonding to resins and rubbers, electrical properties, and dimensional stability. These properties may be used in any of the following applications: filter fabrics, auto-top decking for convertibles, tents and tarpaulins, yacht sails and marine cordage, harvester aprons, anode bags, and agricultural and mine belting.

The last three products mentioned in this chapter are an excellent example of what is known as application research. Although the initial research which culminated in the product itself is given the greater amount of praise and credit, the work that is done on the product in its original form in order to make it available to an ever widening consumer demand is of the greatest importance. This type of reseach has made it possible for the fibers, which in their original pilot plant form had very few outstanding properties or characteristics, to diversify their fields of application by being impregnated with a number of additional characteristics and properties through studies on their chemical structure and methods of manufacture. In their increases application fields they can then utilize all their properties to advantage at whatever job they are performing. It is this type of research that makes the selling of a new product considerably easier, and gives the manufacturer the assurance that his product can be marketed under all types of adverse economic conditions as there will always be some applications whose use cannot be dispensed with.

CHAPTER V

NEW PRODUCTS

This chapter concludes the discussion of the threefold aid to sales, and the other benefits to be derived therefrom, through research as mentioned in the Role of Research. (Chapter II) As stated in that chapter, "If a product is really new, really novel, and is priced right, it will sell on any market, buyers or sellers". Now that the buyers market is not a thing of the future but right here with every industry and in the back of every manager's mind, the importance of this type of research cannot be neglected any more. There is no other branch of the chemical and process industry that demonstrates this statement better than the field of plastics, and due to this fact the greater portion of this chapter is devoted to an analysis of the various plastics, their discovery, application and properties.

In order to simplify the classification of the numerous plastics, and for that matter any new discovery or research program, this discussion is divided into two major classifications. The first part concerns itself with new products that are produced for the consumer who buys them for their exceptional properties for use in his everyday life. The second part of the chapter is concerned with those new products that are used, by and large, by industry and rarely reach the consumer directly.

A. Products for the Consumer

Most of the plastics in use today have been developed within the last twenty years, and, like the airplane and the radio, are undergoing constant improvement. The very first plastic, however, is a product of the nineteenth century, and for it this country may be thankful to the enthusiasm of billiard and pool players. In 1863 Phelan and Collander, manufacturers of billiard balls, offered a $10,000 award to anyone who developed a substitute material for the ivory that was fast disappearing, and was therefore able to demand very high prices.

Many men, lured by this sizable award, put their ingenuity to work. But it was John Wesley Hyatt, an American printer, and his brother, Isaiah, who made something that, while it did not have all the qualities of African ivory, looked much like it. Getting their idea from a medicine kit's collodion (used as a coating or skin on small cuts), Hyatt contrived a mixture of cellulose nitrate and camphor. The resulting compound was white and fairly hard. Furthermore, it had a property that no tusk had; it could be shaped under heat and pressure. In short, Hyatt developed the first of the modern plastics. It was called celluloid, and it became the base from which rose the whole plastic industry.

With the research compass pointed in a new direction, organic chemists began to explore the pässibilities of other similar compounds, called resins. Many years passed before another successful plastic came as a result of this searching, but the scientific world was excited and stayed excited over Hyatt's discovery.

Though work went on at the same time to improve on cellulose nitrate, or celluloid, the second marker of progress in plastics came in a field which differed considerably from thermoplastic cellulose nitrate.

Dr. Leo Baekeland's revolutionary discovery, standing like a Matterhorn above the plateau of modern invention, came out of a need for a superior insulating material. Wood was inadequate. Rubber was fair but expensive, and it left much to be desired. Shellac, though useful, wasn't all the industry wanted; it broke down under heat. Dr. Baekeland put together a mixture of phenol and formaldelyde and with heat and pressure produced a hard, dark, electrically resistant resin, a material better than any previous insulator. He called it "Bakelite", and as the significance of his discovery became clear, his contemporaries called him the "father of modern plastics".

Stimulated by Baekeland's work, investigation went on apace. With Bakelite and Hyatt's earlier find, chemists had at hand the forerunners of the two important families of the plastics world. One, the thermosetting family, was headed by phenol formaldehyde. Formed by heat and pressure, it became impervious to heat. The other class, the thermoplastics, with cellulose nitrate as the patriarch, would, like wax, harden when cooled and would soften when heated. All the plastics that are being produced at present, numbering many hundreds if company specialities and trade names are included, may be grouped into fourteen major types, some of the more important of which are the phenolics and cellulosics, the forerunners mentioned above, the polyamides (nylon), caseins (glues), melamines (Resloom), polystyrene (combs etc.), vinyls (raincoats, rubber like sheeting), acrylics (Lucite), and polyethylene (Polythene).[1]

1. Lucite.[2]

At a banquet in Washington in 1936 marking the founding of the American patent system, guards anxiously eyed what appeared to be identical balls of crystal set side by side on a lighted dias. One ball was of rock crystal and almost priceless. The other - indistinguishable from crystal to the eye - was made of Lucite acrylic resin, a Du Pont plastic. It cost less than $50.

The developement of acrylic plastics, such as Lucite, stems from scientific investigations begun during the nineteenth century. Resins in this category first were made commercially in Germany early in the twentieth century. Work on them also went forward in England, and subsequently research on the subject was carried on in the laboratories

1. Pamphlets of Monsanto Chemical Company, Plastics Division, and Modern Plastics, Incorporated
2. Pamphlets of Du Pont Company, Plastics Department, (See Bibliography)

of the Du Pont Company in Wilmington. By 1937, years after the first resin was synthesized in a test tube, Du Pont investigations had progressed to the point where it was possible to produce commercially the first sheets of Lucite in the plastics plant at Arlington, New Jersey.

One of the most important uses for Lucite was in the manufacture of transparent enclosures in aircraft. For years Federal aviation authorities had been seeking for this purpose a material that would be at least as clear as glass, preferably highter in weight, and less likely to break. At the same time they wanted something better than the plastics thus far used, which were not sufficiently transparent and which failed to stand up under exposure to sunlight and weather. Lucite met those requirements at a time when military aircraft production was beginning to be pushed to meet a national emergency.

The material's resistance to weathering was found to be excellent. It was not readily broken. It was light in weight. No other plastic appreached its optical properties which, by further research, were made superior to any but those of the finest optical glass. Processes were developed for shaping flat sheets of Lucite into noses and other enclosures for tens of thousands of military and civilion aircraft.

The principal ingredient of Lucite is a chemical compound known as methyl methacrylate. It is manufactured at the Du Pont high-pressure synthesis plant at Belle, West Virginia, and is one of the several important synthetics, including nylon, which may be derived from elements of coal, air and water. By four different procedures, Lucite is made as sheets, rods and tubes at Arlington and as molding powder in the new Washington Works, Parkersburg, West Virginia.

Lucite is easily one of the most beautiful of the plastics. It comes close to realizing the chemist's dream of organic glass. Its high transparency, and freedom from haze or color of its own, make it possible to give Lucite any color. Thus, while it is best known in its colorless, crystal form, it is also found in a wide range of transparent, translucent and opaque colors.

With beauty, Lucite combines many useful properties. No highly transparent plastic material in commercial production can match the acrylic resins in their ability to withstand outdoor exposure. In addition, Lucite is a good electrical insulator, is resistant to most common chemicals, and has good impact resistance.

Because of its clarity and because it can be made with a perfectly smooth surface, Lucite has the ability to transmit or "pipe" light around curves. The phenomenon may be demonstrated by directing a beam of light into the end of a long Lucite rod which, with the aid of heat, has been tied into a knot. The light, without being seen throughout the length of the rod, emerges in nearly undiminished intensity at the other end. Out of this phenomenon, and the fact that it has the ability to transmit over 90% of the light rays, has proceeded a whole line of instruments using Lucite rods to illuminate body cavities in dentistry and surgery. Light of good intensity, yet cool and harmless to tissue, may be directed upon a small area through a rod screwed, for example, into a handle containing a flashlight.

Use has been made in the light-piping of Lucite in "edgelighted" murals, screens, panels, and signs. If one edge of a sheet is supported in a frame directly above a fluorescent tube, and if the surface of the sheet is perfectly smooth, the light will be carried through it invisibly to emerge at the opposite edge. But if the surface of the sheet is carved or sand-blasted or otherwise roughened in a decorative pattern or lettering, the pattern will glow with light escaping where the smooth surface has been broken.

Recently, Lucite was used for the first time, in quantity, in making large outdoor signs. As an instance of this developement, a few years ago a large oil company installed a number of Lucite signs at gasoline service stations. The signs were made of two Lucite faces enclosing two cold cathode tubes whose light, spreading evenly through both surfaces, made them shine like electric light globes at night. Natural light, glowing evenly through the signs, gave an effect of daytime illumination. A major consideration in use of the material for this purpose was low upkeep costs.

In addition to their durability in outdoor exposure, the signs required no painting, as their colors were incorporated into the plastic.

For a number of years, Lucite molding powders have been used in the manufacture of lenses and reflectors for automobile tail and stop lights, and in knobs and other hardware fittings and the transparent covers of instrument panels. At present, more than fifty eight parts on fifteen makes of automobiles have been made from Lucite molding powders. In these uses, advantage has been taken of the material's transparency, beauty, ready moldability and weather-resistance, plus its virtual freedom from breakage during automobile assembly.

Considerable quantities of Lucite molding powders are used in making such items as combs and brush backs. The material also goes into the manufacture of costume jewelry, display cases, gift boxes, food covers and such specialized articles as contact lenses, artificial eyes, and cranial plates.

Lucite molding powder, formulated and pigmated to give the appearance of human gums, is used to make dental plates. One composition, specially prepared, is known by the trade mark Lucitone and is distributed by the L. D. Caulk Company of Milford, Delaware. It is processed into plates at dental laboratories by a molding technique adapted to the plaster molds in which this work has to be done. For use in the mouth, Lucite has the advantage of being odorless and tasteless and without toxic effect. It also has no tendency to absorb taste or odor or color from foodstuffs, and is dimensionally stable so that a well fitted plate continues to be comfortable.

Having seen the numerous products and uses that one plastic has been put to due to its exceptional properties in certain fields, one can well imagine the benefit that such a plastic gives to management, both that which produces the articles and that which uses them. Although the Du Pont Company is one of the largest producers of plastic compounds and powders it has many competitors, numbering some twenty five, of which Union Carbide and Carbon Corporation and Monsanto Chemical Company are the most important. Before describing some of the products of these other companies it is well to mention one more Du Pont product, Pyralin, which is one of the latest developements of the cellulose nitrate plastics.

Pyralin is available in a wide variety of colors, and, as most cellulosic plastics, is pliable, tough and durable. It has a moderate specific gravity and a low water absorption. As all thermoplastics it can be readily formed, machined and cemented. The greatest disadvabtage of all cellulose nitrate plastics is the fact that they are exceedingly flammable, and Pyralin is no excpption to this rule.

The best established uses of Pyralin are in such colorful items as fountain pen and pencil parts, optical and handbag frames, buttons, buckles, and toys. It is also used in shoe heel coverings, drawing instruments and tool handles. One reason for its wide application is the fact that Du Pont produces it in the form of sheets, rods and tubes, while most other plastics, as will be seen later, are only produced in one form.

2. Vinylite Plastics[1]

Vinylite is the trade name for the polyvinyl plastics as produced by the Bakelite Corporation unit of Union Carbide and Carbon Corporation. The vinyl plastics may be produced in the form of resins and powders or as a final plastic product and there are a number of chemical combinations that give varying characteristics to the final product. Most of these vinylite plastics are characterized by some of the following properties: colorless, odorless, non-toxic, non-flammable, chemically inert, tasteless, slow burning, and unaffected by ageing.

The vinyl chloride-acetate resins can be produced in the form of molded and extruded plastics, film and sheeting. The former production methods result in such articles as gaskets and transcription records, while the latter are used to make upholstery and handbag material, moisture resistant

1. Pamphlets of Union Carbide and Carbon Corporation. (See Bibliography)

coatings and durable, waterproof fabrics.

The vinyl acetate resins have the particular property of having excellent adhesive strength and are employed for this property for bonding cloth, paper, porcelain, metal, leather and numerous other types of surfaces. They are also used in the preparation of lacquers and for the sizing of textiles, fèlt and straw.

The vinyl butyral resins, third and last of the vinylite group, also have excellent adhesive properties and are used for this purpose in the production of plywood and mica sheets. The product has such phenomenal toughness that it is now used extensively in the manufacture of a permanent, tenacious, interlayer for safety glass.

This one group of plastics, all derived from the same chemical phenomena of polymerization, have thus been able to supply the basic needs of half a dozen industries or more. The initial research work that brought the potentialities of this plastic to light has long been forgotten in the subsequent research to bring forth new variations of the basic polymer that will cater to the needs of an ever increasing and widening consumer market.

3. Phenolic Plastics[1]

The field of phenolics, as started by Baekeland, now comprises a wide variety of products ranging from molding

1. Pamphlets of Union Carbide and Carbon Corporation. (See Bibliography)

plastics and laminating varnishes to resins for paints and varnishes, adhesives, bonding materials and calendering materials. In comparison to the vinylites, all the phenolics are derived from the same basic chemicals, phenol and formaldehyde, although some of the resins are produced by combinations of derivatives of these two organics.

While the phenolics as a class appear in many forms, to the average consumer they are always in the form of pressure molded plastics. As a molded plastic the phenolics have such outstanding characteristics as mobility, dimensional stability, excellent electrical insulation, resistance to heat, water and chemicals, and above all a relatively low price. The molded phenolics themselves vary somewhat in their specific characteristics depending on the type of filler used in the final product. Thus the general-purpose phenolics, which are wood-flour filled, have a well balanced combination of properties that make them ideal for business machine housings, radio and television cabinets, and the everyday telephone.

Shock-resistant phenolics are specifically manufactured for use in applications where the part will require considerable motion in machinery and household equipment, such as electrical bushings, variable speed pulleys, washing machine agitators, table fans and fishing reels. The mineral filling of certain phenolics gives them greater resistance to heat and makes it possible to use them at temperatures as high as 525°F. These plastics are used as handles in electric irons, kitchen utensils, and as bases and fittings on other appliances possessing electrical heating units. In addition to these, a special group of phenolics is manufactured for very limited purposes. The low-loss plastic insulation materials have been developed for high frequency service in the electrical field. Specially resistant plastics are produced to provide protection against water, acids, alkalies, oils, and other types of chemically corrosive products. Phenolics containing graphite are used in the heavy-duty bearings required in steel rolling mills, where the bearings are then self-lubricating. The latest developement in this line of special phenolics has been the X-ray phenolics which are substituting for lead as X-ray shields in many industrial and medical applications.

Although the molding plastics are by far the most common form of phenolics, there are two other major uses for this polymer. The first is as a laminating varnish for the production of laminated plastics, a developement that has many interesting furniture applications. The second is as a resin, where the resins themselves have a myriad of uses. They are used as quick-drying and durable-coating constituents of paints and varnishes, as adhesives for plywood and wood fillers, as bonding materials for high-speed grinding wheels, and as calendering and impregnating resins for waterproofing cloth and making it resistant to chemicals and heat.

The original plastic, Bakelite, can therefore be seen to have come of age since the days that Baekeland was instrumental in discovering its unique properties. Research has gone far to place this plastic, and the whole plastic industry, on the industrial map of the world, and there is no branch of industry that has achieved as phenomenal a success as this one in the production and marketing of its products.

4. Styrene Plastics.[1]

Styrene plastics were first indroduced for commercial application in 1937 in the form of thermoplastic materials for injection molding. Since then they have advanced at such a rate that, today, they occupy a front-rank position in the field of molding plastics. The outstanding physical, electrical, and chemical properties of this unique plastic created an industrial demand for its fabrication into other useful forms. Within a short period styrene film was announced, mainly for electrical insulating requirements. A few years later special processes were developed by fabricators enabling them to produce sheets, tubes, rods, and special shapes from the base plastic. More recent developements are styrene plastic sheeting that is sufficiently tough and flexible to permit punching and stamping, as well as filaments, and fiber.

1. Pamphlets of Union Carbide and Carbon Corporation (See Bibliography)

Styrene plastics, in all their fabricated forms present the designer with an unusual combination of properties that cannot be found in any other material. Superior electrical insulating values have led to their wide spread adoption in high-frequency radio and electronic service. Remarkable chemical resistance, particularly to strong caustics and acids, has solved problems in chemical processing, handling, and shipping. High index of refraction, transparency, and clarity established important uses for the material in the lighting field. Dimensional stability unsurpassed by any other thermoplastic, low specific gravity (1.05), rigidity combined with good mechanical strength characteristics, and availability in a great variety of colors, open up untold possibilities for improved product and package design.

At the present time styrene plastics are being produced in large quantities for display purposes, where they offer light, strong and washable packages for all types of articles. Due to their variety of colors they are used extensively in toys, and in wall tiles.

B. Products for the Producer.

1. Polythene.[1]

Polythene is the trade name of Du Pont's latest

1. Pamphlets of Du Pont Company, Plastics Department; Chemical Engineering, February 1949.

addition to its already wide field of general purpose plastics. At the present time it is the only plastic of its type that is still in a sellers market, and that even after quadrupling output between 1948 and 1949 to produce fifty million pounds in the latter year.

Polythene is one of the very simplest plastics in terms of chemical structure, being manufactured by the polymerization of ethylene, a gas obtainable from petroleum. The fact that it can be polymerized has been known for many years, but it was not until about fifteen years ago that research carried on in England demonstrated that useful polymers can be made if polymerization is conducted under extremely high pressures and at elevated temperatures. Thus major resources of modern chemical equipment and engineering are essential in manufacturing this resin.

Polythene is a white translucent material of somewhat waxy appearance. Lacking the complete transparency and sparkle of Lucite acrylic resin, polythene is sold less for its appearance than for the most impressive combination of good physical and chemical properties to be found in any single plastic. It has excellent electrical properties, is the lightest of all commercial plastics, has high chemical resistance, is tough and flexible at temperatures well below the brittleness points of other plastics, and has a very low rate of water vapor-transmission. In addition, it contains no plasticizer, is tasteless, odorless, and non-toxic, is available in a wide range of colors, can be heat-sealed, and is easily molded, extruded, and machined. Its relatively low price coupled with its low specific gravity make it an economical material for many uses.

Its outstanding electrical properties dictated uses for polythene when it first became available in commercial quantities at about the start of World War 11, and all supplies were allocated for military purposes. The most important use was as an insulator on infantry field wire, where a relatively thin coat provided adequate insulation. This, together with low weight of material, made possible a major reduction in the weight per mile of the wire, which in large part was carried on the backs of soldiers and payed out over the ground. Since the war, electrical insulation has continued to be a major field for polythene, particularly in high-frequency equipment. Oil-burner and neon sign cables (GTO wire) in five thousand to fifteen thousand volt sizes are insulated with polythene, where high moisture resistance, exceptional electrical properties and long life make it an ideal material. Thousands of miles of coaxial cable have been produced, using insulation discs of polythene in the coaxial units- as many as 506,000 discs per mile in a typical cable. It is also the insulating material in several types of television and FM lead-in lines, where power loss and distortion are minimized, providing strong, clear reception.

One of polythene's earliest and most successful uses has been the packaging of frozen poultyy, where low moisture loss is essential to prevent dehydration. The bags, made from flat tubing with a rounded heat-sealed end, remain tough and flexible during long exposure to subfreezing temperatures, and are transparent enough to make the bird visible to the shopper. A major meat packer is using large polythene bags for packaging veal carcasses weighing from fifty to sixty pounds.

Manufacturers have adopted polythene film for the packaging of such metal parts as brass fittings, surgical screws, ball bearings, and electronic and hardware parts. It is ideal for this purpose because it has excellent tear strength, and cuts or nicks do not tend to "run". Liners for bags and for metal and fiber drums are used for packaging chemicals, pharmaceuticals, adhesives, and foodstuffs, replacing glass containers and specially coated metal drums. This permits the use of lower-priced outer containers which usually have a lower tare weight. Because of its exceptional chemical resistance blow-molded polythene bottles are used for hydrofluoric acid and other corrosive chemicals and solutions.

Polythene film is used as continuous backing between layers of uncured rubber before vulcanization, and as envelopes for each roll of uncured rubber. The non-sticky polythene backing peels cleanly and prevents adhesion within the roll, and the envelope keeps the "camel-back" (uncured rubber) tacky for use.

For years, medical science felt the need of a flexible material that would be tolerated by body tissues, and, therefore, could be used safely in making surgical repairs. Late last summer, two groups of research physicians reported the successful experimental use of polythene for that purpose. One, a group of Boston neuro-surgeons, described in the Journal of the American Medical Association the use of thin polythene film to replace membranes in brain surgery. At about the same time, physicians of the Mayo Foundation at Rochester, Minnesota, told a meeting in New York City of the American College of Surgeons about the replacement of bile ducts with fine polythene tubing.

2. Plastacele.[1]

With Plastacele this chapter ends the more common plastics which are produced under their trade names by the plastic manufacturers. This, as most of the previous products, is the result of research to illustrate Du Pont's registered trade mark, which, in part reads, "Better things for better living..... through chemistry".

Plastacele is a cellulose acetate plastic and is only

1. Pamphlets of Du Pont Company, Plastics Department. (See Bibliography)

produced in the form of sheets, as its major application is as a visual guard, either in the form of a visor or a dial covering. It has excellent impact strength and moderate specific gravity, and is inert to most vegetable and mineral oils. This characteristic has been the main reason for its application in such varied products as covering for hospital charts and blotters, drafting instruments, industrial faceshields, lenses for various types of industrial and drivers' goggles and welding helmets, machine guards and motorcycle windshields and taxicab partitions. This plastic can therefore be seen to have given industry and the public a means for greater safety with undiminished visibility and this is of the greatest importance in all operations.

3. Teflon.[1]

The outstanding product of the plastic laboratories in the past few years has been tetrafluoroethylene resin, given the trade name Teflon by Du Pont, its originator. The resin is made by polymerizing gaseous tetrafluoroethylene to yield a solid, granulas polymer. The outstanding properties upon which many important uses are based are its toughness over a wide range of temperatures, its excellent electrical properties over a wide range of frequencies, its extreme inertness to chemicals, and its re-

1. Ibid; Chemical Engineering, March and November 1949, January and February 1950.

sistance to heat.

The chemical resistance of Teflon is outstanding. It withstands the attack of practically all chemicals except molten alkali metals. It has been boiled in many solvents, including a variety of halogenated hydrocarbons, ketones, esters, and alcohols, without swelling or any other sign of attack. Teflon can be boiled in aqua regia, hydrofluoric acid, sulphuric acid or nitric acid with no change in weight or properties. It is equally resistant to the attack of strong alkalies. Since it can be used over the temperature range of -320°F.,to 550°F., the number of applications for this plastic are unlimited.

Teflon possesses exceptional electrical insulation properties and due to the fact that it can withstand temperatures in the vicinity of 400°F. for any length of time, and of 500°F. for short periods of time, it is well suited as a insulant for the wiring of transformers and motors.

Teflon was a war developement, but due to the difficulties of manufacturing and applying it its applications have been severely restricted till now. Recently, however, Du Pont research men discovered that it could be made as a suspensoid, a form in which fine particles of the plastic are held suspended in a liquid. This led to equally important discoveries - how to make Teflon adhere to metals and how to make finishes that could be sprayed. Out of this new suspensoid form of Teflon, five new finished product developements have been evolved, which are expected to have considerable industrial usage when sufficient suspensoid becomes available. The five products and their uses are listed and described below.

a. Industrial Finishes.

These industrial finishes are applied with paint-spraying equipment to metals. The finishes will adhere to most metals, such as steel, stainless steel, aluminum, brass, copper, and to glass (after sand-blasting), porcelain, and brick. There are three types of Teflon spray-coatings - primer, intermediate, and finish. The process of applying each is similar, first spraying them on, after having thoroughly cleansed the surface, removing all oil and greases, then letting them dry, followed by a fusion of the particles by baking them around 750°F. and quenching when this has been achieved. The thickness of the finish necessary to give protection against corrosion depends upon the nature of the chemical to which the finishes are to be exposed. The primer is always used as that is the secret of adhesion. An intermediate coat may or may not be used as its purpose is to toughen the finished lining. The number of finished coats are the variable numbering anything from one to six.

The price of tanks and other containers that will eventually be produced with Teflon linings should compare very favourably with those of the glass and rubber lined variets, and in addition have properties that are far superior to those of the other tanks. Several fabricators have already started setting up operations that will enable them to convert to Teflon lined tanks as soon as Du Pont produces commercial quantities of the necessary suspensions.

b. Wire Enamels.

The largest application for wire enamels is in the insulation of magnet wire for the windings of motors, transformers, and generators. In this application their greatest asset is their heat resistance. Teflon insulation will stand a much higher temperature than ordinary insulation, operating at 400°F. instead of 220°F. for ordinary insulation. In addition to this a Teflon insulated motor can operate continuously at 400°F. and for short periods at 500°F. Thus, if the insulation can stand higher temperatures it is possible to put more current through the conductors, receiving much more power out of the machine. On a motor, for instance, Teflon insulation would increase the horsepower output by 25 or 50%. Or the other way around, to get the same horsepower the motor could be greatly reduced in size and weight. A transformer would only weigh a third as much - and it would last three times as long. This weight factor is of great importance in aircraft motors, where a big transport plane may carry as many as thirty motors and thirty transformers, whose reduction in weight will enable the plane to carry considerable additional transportation weight, besides lasting longer. The size factor naturally also makes a considerable reduction in the cost of the materials going into the motor as much less copper will be used.

c. Extrusion Compounds.

Extrusion compounds of Teflon resin have been developed for heavier insulation than is possible with the wire enamels. The heavier coatings have exceptional dielectric properties at high-frequencies and, for this reason, are expected to be adopted widely for radar and television installations. In applications where conductors are wanted which can withstand high temperatures these extrusion compounds will also find much use. This would include the wire in electric ranges and other appliances, thermocouple leads, aircraft ignitions and large amounts in large motors, transformer coils and other electrical equipment.

d. Unsupported Film and Coated Fabrics.

One of the uses for unsupported film and coated fabric is as electrical tapes superior to those now available commercially. They may be employed for wrapping electric coils, or as protective layers between coils, or as condenser films.

Glass fabrics coated with Teflon, and unsupported Teflon film, will complement the wire enamels and extrusion coatings in electrical equipment, and also will have non-electrical applications. The coated fabrics may be used in the electrical industry as slot liners, coil wrapping, layer insulation, and, possible, as a substitute for mica sheet in transformers and condensers. In the chemical industry, the fabrics may be used in the manufacture of protective clothing, or as gaskets, conveyor belts, and flexible ducts for hot, corrosive gasses. These coated fabrics are simply sheets of Teflon resin reinforced with glass cloth, and these may be laminated into strong, solid material of almost any desired thickness by bonding under heat and pressure.

e. Raw Suspensoid.

Raw suspensoid is available at the present time at about $75 a gallon which amounts to a total cost of $10 per pound of solids. At the present time the Du Pont Company is soliciting the cooperation of research organizations in many fields other than those already mentioned in the hopes that they will find radically new applications for this exceptional plastic. These will show more so than now that this new type of plastic, which only has competition from M. W. Kellogg's Kel-F, in even a lower stage of developement, is giving management a completely new field from which to take products to help it in its numerous production problems in the chemical and process industries.

Teflon is a completely new product, so new, as a matter of fact, that the products being placed on the market at present are still being manufactured at the pilot plant in which the process was first developed. Its characteristics and functions to date have shown it to have favorable possibilities, and these facts are presented to potential users of the product in much the same way as they are presented here, in the hope that one will find additional applications for the product and strengthen its market for the future in order to make it an indespensable raw material for industry. The application research on this new product has only just begun and only the years ahead will show how well it is succeeding in bringing Teflon to the widest possible market at a price that makes it available to all consumers.

CHAPTER VI

COMPLETE UTILIZATION OF MATERIALS

The phase of research that is being discussed in this chapter has only been in existance for a relatively short time. The increased amount of research being conducted at present was caused largely by production for the war effort which consumed larger quantities of America's natural resources than would have been used during a normal period of business activity. Although the United States is the possessor of some of the world's richest natural resources of metals, oil and timber, none of these are inexhaustible . This America is realizing with a feeling of frustration as it bends all the forces at its disposal to try and stop the depletion of some of its more important raw materials.

The raw material which has been given the most publicity in this regard is petroleum, which will be discussed in greater detail in a subsequent chapter.[1] Another major source of raw materials, though not given as wide publicity, is the American forests, and a third natural resource that is dwindling fast is that of iron, where statements have been made to the effect that the Mesabi range has only another decade during which the mining of iron ore will be an economical operation and United States steel manufac-

1 Chapter VIII

turers are seeking reserves of iron ore known to be available in Labrador, Venezuela and the Canadian Shield.

With this somewhat insecure situation as the outlook for so many important raw materials of industry, it is only too obvious that something drastic had to be done. These raw materials are one of the most important factors which make the American system of free enterprise what it is today and without them the management of the industries that comprise that system would be hard pressed to keep their competitive position. Research has been called upon to help in this crucial situation and has come up with a concept that was unknown before in the eyes of management. This is the concept of "complete utilization" as stated in the title of this chapter. This utilization refers not only to the raw materials themselves, as explained above, but also to the by-products that result as a part of the process of manufacturing the final product. In contrast to the manufacturing industries, where waste and scrap can usually be utilized in its original form, the waste of the chemical and process industries has usually to be converted by further processing till it is in the form of a usable product. It is the research involved in this further processing of waste that constitutes the second half of the "complete utilization" referred to above.

A. Utilization of Raw Materials

As stated above, one of the most obvious wastes in the utilization of raw materials occurs in the timber industry, whether the wood be used for construction, or as a raw material for such industries as rayon, cellulose, pulp and paper. Detailed studies have been made in the Douglas fir regions of the Pacific northwest which indicate that 20% of the original timber stands have been left after logging operations in the form of defective logs, broken tops, split logs, knocked-over trees and windfalls, and that 19% of the sawmill residue produced by the various operations conducted there are never used. The huge quantities of these wastes and the values to accrue from their conversion to desirable products have lately been given much publicity in that industry. It is partly for that reason that waste utilization has been considered an essential feature of the conservation and developement of the nation's forest resources which offer such a bounty of raw materials to industry and are therefore part and parcel of management's daily problems.

The two major sources of raw material wastage in the timber industry are the waste wood of timber stands referred to above and the sawdust which results from the cutting and sizing of the timber in the lumber mills. These two types of waste are utilized in entirely different ways, each the result of many years of painstaking research, culminating finally in a process that produces a product that has commercial possibilities and results in considerable financial gain to the entrepreneur. While the timber stand wastes are usually converted to hardboard or presswood panels for the construction industry, as illustrated by the product Masonite, the sawdust is made into industrial carbon or utilized as a raw material for various industrial chemicals by a process known as fluidization, previously utilized by the petroleum industry exclusively. Masonite has been produced on a commercial scale ever since 1925 and since then has seen many improvements in its properties and adaptability. The carbonization process, on the other hand, has only been in commercial production for less than a year and the research and developement of this method of utilization is therefore given in considerable detail in order to demonstrate the functioning of research in its attempt to aid management in the solution of the problem of "complete utilization".

1. Carbonization of Sawdust and the Production of Chemicals.[1]

A critical shortage of certain types of industrial carbon is developing in some parts of the world. One solution to this shortage lies in the utilization of the waste products of industry and agriculture. The Stanford Research Institute of Stanford, California, has developed a process that answers the need. Using the technique of fluidization, controlled carbonization of finely-divided, carbon containing materials has been achieved, and carbon and chemicals produced.

1. Pamphlet of Stanford Research Institute

Fluidization is the new technique that has been extensively developed during the last ten years by the petroleum industry for the more efficient catalytic cracking of petroleum. This developement represents one of the outstanding achievements of technical research in the chemical and process industries in recent years and is explained in some detail in Chapter IV.

In addition to the catalytic cracking of petroleum, new uses include the catalytic oxidation of naphthalene to phthalic abhydride, previously made by a complex synthesis, the calcining of lime, the modified Fischer-Tropsch process for the synthesis of gasoline, discussed in greater detail under the section on the production of oil from other sources besides natural oil,[1] and the gasification of coal. The possibilities for future usefulness of the technique of fluidization are great, and in the next decade greater efficiency will be gained in processes that can take advantage of fluidized systems.

One of the promising applications of fluidization is the carbonization of waste products of the lumber industry. The decreasing supplies of timber and the continuing industrialization of the world make it increasingly important to utilize a greater portion of each tree. Carbonization is one of the most promising methods of converting wood wastes

1. See Chapter VIII

into a series of valuable products, such as charcoal and chemicals. The characteristics of a fluidized bed make fluidization particularly suitable for carbonization of saw dust and other wood wastes.

In its research the Stanford Research Institute utilized kiln-dry redwood sawdust as the raw material for carbonization. Redwood was selected to make these tests since this wood contains large quantities of valuable phenolic chemicals. In addition, large quantities of redwood wastes are available in the Pacific Coast area of the United States, where a carbon shortage exists.

The carbonization experiments have definitely shown that sawdust can be fully or partially carbonized by fluidization. The results of these experiments also show that the distillation of wood chemicals proceeds very rapidly and that chemical condensates are produced that are primarily clear liquids. The results of this exploratory program indicate the practicability of a fluidized carbonization process. A high-quality charcoal was obtained which appears to be suitable for many industrial carbon uses. Preliminary tests on briquetting the chars were also extremely satisfactory.

The process for the fluidized carbonization of redwood sawdust appears economically sound. Sawdust and other redwood wastes have only a limited value as a fuel and therefore are cheap raw materials for the process. The demand for charcoal is substantial on the West Coast of the United

States and will increase rapidly as more of it becomes available and as the more expensive forms of carbon are replaced. The chemicals will also supply a strong demand in the United States West Coast area.

High yields of phenolic chemicals produced in the process will find ready markets. The gas products of the reaction will provide the heat necessary for the endothermic reaction, and the excess will be utilized for pre-drying the sawdust; therefore, no additional heat will be required for the reaction. Plant construction will be simple and the cost low. The labor requirements will be small because of the simplicity of the operation and the fact that the process is continuous. No serious flaws have been found in the process to date. The construction and operation of a commercial plant is an immediate possibility as is demonstrated by those that have already been built since this process was perfected.

Further processing of the charcoal is a possibility in the developement of the process. Much work has already been completed on the activation of charcoal in a fluidized bed. A commercial plant has already been constructed in France. Results to date indicate higher efficiency, better quality, greater yield, and closer product control than from conventional methods. Other further processing of the charcoal to be considered include graphitization and impregnation.

Application to wood wastes other than redwood will receive attention in the future developement of the fluidized carbonization process. Some of the more important of these wastes are from pine and fir trees. The tonnage of wastes from these trees alone exceeds all other wood wastes in the United States. Controlled fluidized carbonization of pine-tree wastes may be expected to furnish large quantities of turpentine in addition to the usual wood chemicals such as methanol, acetic acid, and acetone. The fluidized carbonization of pine and fir wastes can there be seen to be a potentially large new industry in the United States.

A number of agricultural wastes constitute another source of a promising raw material for carbonization by the fluidization process. Peach and apricot pits and nut shells are examples of agricultural wastes that are presently being carbonized in batch processes. The use of fluidization should offer better carbonization efficiency. Waste agricultural products having no present use or value should be evaluated as possible raw materials for this process. Each waste must be considered individually and the carbon and chemicals produced from the waste evaluated in terms of the economy of the products in a particular location in the world. Waste products do not constitute the only potential raw material for fluidized carbonization. Wood, particularly in sections where it is burned as a fuel (thereby destroying wood chemicals), could be successfully carbonized producing carbon and chemicals.

It is known that the chemicals contained in wood could be the basis of a large chemical industry if the various chemical components could be obtained and separated economically. In the fluidized carbonization of wood, a method has now been developed whereby the chemical content of trees can be more fully utilized. The simultaneous production of carbon in this process is a possible solution to the problem of carbon scarcity in certain sections of the world. The application of this process to carbon-containing materials other than wood may well provide the basis of a new industry for the production of carbon and chemicals, and may assist in the development of the industrial potential of agricultural regions.

The above analysis illustrated in considerable detail the research involved in the fluidized carbonization of sawdust and the numerous useful products that are obtained from the process. Materials that would have otherwise gone to waste are being utilized to start up completely new industries, to bring additional products to the market and to bring considerable financial gain to a management whose profit margin is continually decreasing. Although this is at present the most important discovery in the field, there are numerous other methods of utilization of primary timber waste, a number of which are discussed in the paragraphs that follow.

The Oregon Forest Products Laboratory has proceeded on similar lines as the Stanford Research Institute in producing carbonized saw dust or softwood charcoal. They, however, are producing the same endproduct by means of a retort kiln, and are putting their charcoal into the form of briquettes which are distributed to industrial users for trial purposes. They have already been found to have particular properties for use in electro-metallurgical plants established near hydroelectric power sources in the Columbia Basin, in electric furnaces, in foundry work and in the manufacture of carbon disulfide.[1]

2. <u>Waste Utilized by Integration</u>[2]

Another form of sawdust utilization has come about through the greater use of waste wood, in the factory and mill, by means of integrated operation, where the research has been in the form of balancing the production of the integrated parts so as to achieve maximum benefits. A good illustration of this is a pulp mill set up in conjunction with a lumber mill. One such mill opened in 1949 in Springfield, Oregon, as the latest in the group of Weyerhaeuser Pulp Division pulp mills. This Springfield mill will make 150 tons per day of kraft container board. Simultaneously with the construction of the container board plant there was built a saw mill and remanufacturing plant to handle 300,000 board feet per day. The by-products of the saw mill are the raw materials for the pulp mill. The size of the sawmill was established by the amount of timber which was

1. Pamphlets of Oregon Forest Products Laboratory (see Bibliography)
2. Chemical and Engineering News, January 2, 1950

available from the company's holdings on a sustained yield basis. The size of the container board plant, however, was established on the basis of using the by-product material available from the saw mill and logging operations of the company, together with farmer logs, trim, edgings, and slabs from other sawmills in Lane county where over 100 sawmills are located.

3. Chemicals from Wood Wastes[1]

Wood ranks next to coal and petroleum as a raw material for the production of chemicals and has certain advantages over both. The chemical processing methods are still in their infancy but there are a number of chemicals that have been produced from wood since time immemorial and others that have only lately been extracted as a result of a great deal of research on the subject. In the former category are the tanning chemicals from the bark of the oak and hemlock and rutpentine, while among the chemicals to be produced from wood within the past decade on a pilot plant scale are ethyl alcohol, furfural, neutral oils, cyclic alcohols, and liquid fuels. A large amount of these chemicals are derived from the bark of the trees which in the case of the Douglas fir has a content of extractives upto 30%.

4. Utilization in the Hardboard Industry[2]

The timber stand wastes are utilized largely in

1. Chemical and Engineering News, June 27, 1949
2. Pamphlets of Masonite Corporation

the form of hardboard as mentioned previously in connection with Masonite. The masonite process, because of its unique method of converting forest products to hardboards, with a utilization of 65-70% of the log, including the use of logs that would ordinarily be considered logging waste, together with the relatively unadulterated release of the hemicellulose fraction as a by-product, achieves a total wood utilization of close to 90%. This may be favorably compared to the utilization of the other industries using wood as a raw material, where the lumber industry utilizes 35-50% of the log, the pulpwood industry 40-50%, and the veneer industry 45-65% of the log entering the mill, after having only brought approximately 80% of the timber stand to the mill and leaving the remainder as waste.

5. Pulp and Paper from Dead Timber[1]

As a final example on the utilization of timber stand wastes there is the proposed pulp and paper mill along the Colorado River between Rifle and Glenwood Springs. This mill would utilize millions of cords of dead timber from the forests of western Colorado-timber killed by beetles. The utilization of this wood has involved considerable additional research on the part of the paper manufacturers and has resulted in a process that will produce a product as good as any produced by using high grade lumber as raw material.

1. Chemical Engineering, January 1950.

The mill will stake Colorado to a new industry with a payroll of more than two million dollars a year, and it is estimated that the mill could operate for more than thirty years on the timber in the region. A pulp industry would boost population in the mountain area by an estimated eight thousand. It would mean a $150,000 annual expenditure increase by the company on roads in the forest areas, and the counties would get hundreds of thousands of dollars from the company over a thirty year period for timber cuts and forest fees.

B. Utilization of Process Wastes

Whether a chemical plant lies deep in the heart of a big city, along a major river, or a bubbling brook, the disposal of liquid wastes has always been a major problem to management. The seriousness of this situation was emphasized a year and a half ago when a Federal law was passed giving aid to State and local agencies in enforcing pollution laws already on the books, and sparking the passage of many new regulations. Cities which once took almost any industrial wastes into their sewers are beginning to realize the cost and are asking industry to share the burden.

Management in the chemical and process industries is now face to face with this situation, and although many of them have for years been dabbling with the idea of waste didposal only too few have found a solution to their problems. Those industries having the greatest liquid process waste problems are that of pulp and paper, grain liquor, and steel galvanizing.

The problem of liquid process wastes may be solved in one of two ways. The first, and that most often used, is to treat the wastes in such a way that they either lose their harmful effects in the streams or rivers into which they are dumped, or produce a final product that can be sold on the market to serve a specific purpose and whose sale would at least cover, if not bring a profit over, the cost of producing it. The second method, and one that has only rarely been found, is to change the actual manufacturing process in such a way that actually no wastes are produced and all materials produced are converted back to products that can be utilized in the plant itself, thereby saving large sums of money in the purchase of raw materials and the lack of disposal problems.

Quantitatively speaking the largest amount of liquid process wastes occurs in the pulp and paper industry, where, for every ton of wood converted into pulp by the sulphite process alone, another ton is discarded - most of the discard being in the form of lignin and wood sugars in the waste liquor. More than two million tons of solids per year are thus run into the streams and rivers of this country and lost to the manufacturer forever as a source of raw materials. To help solve these problems which exist throughout the length and breadth of the United States in the pulp industry the various pulp producing companies have banded together and formed the Sulphite Pulp Manufacturer's Research League, situated with its research facilities in Appleton, Wisconsin, the largest pulp producing State in the country. The League was organized in 1939 with contributions of 10¢ per ton of pulp produced by every plant, which resulted in an income of approximately $65,000 a year, but due to the increased requirements of the research staff this quota was raised to 27 ½ ¢ per ton in 1949.[1]

1. Yeast Converts Waste to Stockfeed.[2]

The constituents of sulphite liquor that cause the greatest amount of harm are the somewhat innocent-sounding wood sugars, and not, as is usually the belief, the strong chemicals used in the pulping process. The cause of the trouble in regard to the sugars lies in the fact that aquatic micro-organisms already in the stream into which the waste liquor is lead flourish on the sugar and are stimulated in their growth and multiplication. As the organisms multiply in still or small waters they reduce the biological oxygen of the stream below the levels needed to sustain fish life which either migrates to better waters or dies.

Industrial research has found a process for obtaining feed yeast and feed proteins from waste sulphite liquor at competitive costs utilizing the sugars that are in it.

1. Business Week, February 5, 1949
2. Business Week, November 24, 1945; November 9, 1946; February 5, 1949.

This method employs none of the standard commercial yeasts but rather a type of wild yeast known as torula, which when dried makes a valuable vitamin and protein supplement for livestock and poultry feed. Besides being high in vitamin content the product is only missing one of the essential amino acids from the proteins, which, however, can be easily and cheaply added to the endproduct.

Yeast production of stockfeed from sulphite pulping waste liquor is not new and has been employed in Europe for many years. This product from German pulping mills was used throughout the war for army horses and after the war, during the drastic food shortages of 1945-48, almost exclusively for human food. Similar feed constituants have been used a great deal for dairy and meat production in the Scandinavian countries while the war cut off normal sources of feed. But European processors of waste sulphite pulp liquor face no such low-cost competition as the various American sources of feed supplement for animal and poultry consumption, supplied largely by the liquor manufacturers in the form of the nutritive elements from spent grain liquors, and the waste products remaining after the production of ethyl alcohol from Cuban blackstrap molasses.

The American process has for the first time brought the price of the feed to a level where it can compete with the products of the other industries as mentioned above. Wisconsin pulp mills that supported the original research can produce 25,000 tons of feed yeast and feed proteins a year by this process, although at present only one plant is producing it on a trial basis, which has, however, proven the feasability of the process and is manufacturing about 1,200 tons per year. The large Wisconsin dairy industry offers a handy market for the local mills which will commence expansion on that line in the very near future.

2. Fermentation of Waste to Ethyl Alcohol.[1]

In Germany and some of the Scandinavian countries alcohol is made by the neutralization, fermentation, and distillation of the waste liquor from sulphite pulp mills. Attempts have been made to produce alcohol in the United States by this method but the cost had always been considerably higher than that for producing the same product synthetically or from molasses. Considerable research on the methods of production and the chemistry of the process has resulted in the discovery of a new method for producing ethyl alcohol from waste liquor, and at present a plant is in operation in the remote Northwest, in Bellingham, Washington, producing two million gallons of alcohol annually. The reason for this location is twofold. In the first place it is right in the heart of the pulping country, and waste liquor is expensive to transport due to its bulk, and secondly it is far removed from the Cuban sugarcentrals which

1. Business Week, November 24, 1945; Lucrative Lignin by Allen Abrams

makes the price of alcohol from that raw material relatively higher in the area.

3. Lignin, Chemical Intermediate with a Future.[1]

The lignin and cellulose fractions, which make up the other half of the waste liquor, also have various methods of utilization, some of which have been used for some time while others are only just seeing the light of day. The best known of the products that has been made for quite some time from this fraction is vanillin, the fragrant constituant of vanilla flavouring. The production of vanillin, however, only consumes a fraction of one mill's waste liquor in completely satisfying the requirements for this flavouring material in the United States. For this reason some people are of the opinion that lignin may be a rival of coal tar in the field of intermediates for other products. The vanillin, or vanillic acid, which is its original form, also has possibilities in the fields of dyes and plastics, which are, however, relatively new products and have not as yet been produced on a commercial scale. This short referrence to the subject is evidence enough that there are great potentialities in this fraction of waste liquor. On top of the work that research has already completed, it is progressing at a rapid rate to produce more and more ways of utilizing lignin and to give this seemingly unlimited raw material a market.

1. Ibid

4. Tall Oil from Kraft Mill Waste.[1]

Having discussed the ulilization of waste liquor from the sulphite pulping operation in considerable detail it is interesting to be able to compare it with the products that can be produced from the waste liquor of the sulphate pulp industry. This process produces kraft paper and uses the pine tree as its source of pulp, the industry in this country centering largely around the areas where the southern pine grows. The kraft mills pulping southern pine require 4,500 pounds of wood to make one ton of kraft, which is less than a 50% yield. This can therefore be seen to be one of the largest sources of supplementary raw material in industry today as there is no immediate shortage of pine for the kraft industry and the tree can easily be grown on extensive tree farms.

The major product recovered from kraft pulp liquor waste is tall oil. The tall oil recovery process was first developed in Sweden about thirty years ago. However, the pioneer of the industrial application of the process was the Spangenberg Werke, Hamburg-Eidelstadt. Germany processed 12,000 metric tons of tall oil a year during the war. Although the process was not brought to the United States until the middle thirties this country was producing 10,000 tons in 1937 and ten years later had increased production to the phenomenal quantity of 125,000 tons a year. The time is not

1. Chemical Engineering, May 1948; Pamphlets of National Southern Products Corporation

too far distant that the rapidly expanding sulphate pulp industry may be recovering a total of 200,000 tons annually from its waste in the form of tall oil. A ton of pulp yields from 70-90 pounds of crude tall oil and a plant making 1,000 tons of pulp a day can recover from 35-45 tons of crude tall oil from its sulphate waste liquor.

At the present time, largely through the research of the three major tall oil producers, namely National Southern Products Corporation, Union Bag and Paper Corporation, and Gaylord Container Corporation, during the greater part of the war and immediately after it, there are some forty two industries which use tall oil for a variety of products, a number of which are mentioned briefly hereafter. Tall oil is used as a combined emulsifier and adhesive in certain types of industrial sprays and weed killers. It is used in the manufacture of low priced soaps and disenfectants for the farmer and as a cattle spray. In the line of asphalts, tar and pitch, it is blended with bitumens or pitches to provide compounds having special properties such as roofing formulations, asphalt flooring compositions, and in crack and joint filling compounds. It is used in the manufacture of soap base asphalt emulsions in the highway construction industry and extensively in road paving additives for asphalt and tar to improve the coating and anti-stripping qualities of the bitumen when mixed with crushed stone, gravel and sand in either the wet or dry state. In the chemical field it is used as a source of fatty acids and higher alcohols for the pharmaceutical and related fields. Tall oil is finding more and more applications in the foundry as a component of core oils, and also as a component of oil-well drilling muds where it increases the efficiency of such materials by greatly reducing the water loss in the drilling operation. While on this topic it might be mentioned that the oil is also used extensively as a flotation agent in the concentration of ores. In the manufacturing of linoleum and oilcloth large amounts of crude tall oil are used for base materials and refined tall oils are used in the linoleum industry as esters where color is important. Tall oil is saponified or sulphonated and usèd in cutting oils, lubricants, and soaps for metal cleaning. One of the largest users of tall oil is the paint and varnish industry, where it is used for esters and as an emulsifying agent for water base paints. Tall oil is also used as a textile processing oil and in the paper, plastic and leather industries.

The greatest asset in the utilization of tall oil in comparison to its competitive products is the fact that even after the addition of reagents the esterified product sells for less than these products, fats oils, and fatty acids. During the war, when supplies were short and supplies for oils, fats, and fatty acids were great, considerable testing in the laboratory and in the fields proved that tall oil had properties which made it suitable in enumerable applications. Soon technical men realized that this interesting mixture of fatty acids had many practical uses in industry and tall oil took its rightful place amongst standardized industrial raw materials. Since 1946 the "substitute" consumers of tall oil of the war years have disappeared and this by-product of the kraft paper industry has come of age and increased its applications considerably by the further research of the organizations mentioned previously, who are among the largest producers of tall oil in this country.

5. Process Wastes in the Steel Industry.[1]

The chemical and process industries, however, are not the only ones that have waste disposal problems of a chemical nature, which have been solved by chemical research. This fact may be brought out by the example of the steel industry where one of the major waste disposal problems is that of pickle liquor and zinc waste, a byproduct of the galvanizing of the steel.

Steel is cleaned in strong hot solutions of sulphuric acid which in the process of cleaning dissolves some of the iron. The resulting solution of ferrous sulphate is very difficult to dispose of and the States are insisting that it shall not be dumped into the streams. The conventional way of disposing of the spent pickle liquor is to neutralize it with lime, but besides being very costly this

1. Chemical Engineering, March 1949.

method still leaves the problem of getting rid of the sludge that results.

To cope with this problem the Wheatland Tube Company of Wheatland, Pennsylvania, spent many years of research on devising a method of disposing of the spent pickle liquor in some wat that would not only get rid of the harmful characteristics of the liquor but would also produce a product that could be sold on the market at a profit. This research was finally chrystallized in the form of the process and plant of the Maneely Chemical Company, a subsidiary of Wheatland, which processes the latter's spent pickle liquor and zinc waste to form three salable products.

The three raw materials for the new plant are the spent pickle liquor, zinc waste and chlorine. The spent pickle liquor comes from the plant in which the steel pipes are pickled before being galvanized, this latter operation furnishing the zinc wastes in the form of sal skimmings and raw ash. The only raw material for the reaction that has to be purchased is the chlorine which is received in tank cars. In most cases the zinc wastes are sold for only a fraction of their zinc value and it is this low price for zinc that makes the Wheatland plant profitable. Every pound of zinc that enters the plant leaves either as zinc chloride, zinc sulphate, or as metallic zinc.

The process itself results in all the raw materials ending up as salable products. The iron as ferrous sulphate in pickling adid reappears as the iron pigment, ferric hydrate. The sulphate of the pickle liquor furnishes the sulphate radical for the zinc sulphate. The chlorine appears as the chloride radical of zinc chloride and the zinc appears in the zinc sulphate and zinc chloride in a reacted form instead of as a metal. Current sales price for the last two named compounds is $7.00 per 100 pounds[1], which give a very good estimation of the sales value of these products. The ferric hydrate is used in the Wheatland plant as an iron pigment.

Just for the disposal of the waste products mentioned above this seems to be a long and complicated chemical process. But it must be recognized that most industrial wastes are chemicals of low market value. The best way to dispose of these unwanted chemicals is to convert them into marketable products and this is largely what the new Wheatland plant has accomplished.

6. Sulphur Recovery in the Petroleum Industry.[2]

Returning to the chemical industries, the petroleum companies are faced with the problem of disposing of two products which result as part of the refining process for the oil or natural gas. One is the hydrogen sulphide gas extracted as a waste product from "sour" natural gas and the

1. Chemical and Engineering News, January 23, 1950
2. Chemical and Engineering News, June 20 and October 10,1949 and Chemical Engineering, November 1949.

other is the acid sludge remaining from the treatment of petroleum with sulphuric acid in order to remove the evil smelling mercaptans on the way to produce refined gasoline. Both these products are treated in such a way as to produce elemental sulphur as a final product, while in the case of the gaseous waste a "sweet" processed gas is made available which can be used as a fuel.

The process of extracting sulphur from hydrogen sulphide was first patented in England by C. F. Claus in 1882 but it was not till the middle thirties of this century that research had found an economical method for doing the job in order to produce a product that could be sold at a profit. Due to the fact that it was always largely dependant on imported sulphur Germany produced 50,000 metric tons in 1938 from coke-oven gas (also containing large quantities of hydrogen sulphide) using the same method. Mathieson Chemical Corporation, through the acquisition of Southern Acid and Sulphur Company, Inc., in February of 1949 obtained the only two plants in this country with a record of successful operation in the high recovery of elemental sulphur from hydrogen sulphide which had been operating for six years. According to Mathieson, their process is more economical than the German method.

Starting with the simple reaction of hydrogen sulphide and sulphur dioxide, the complicated, modern engineering data was worked out at the Ohio State University, and employed by Southern Acid in their Arkansas plants. The hydrogen sulphide stream of the "sour" natural gas is divided into two parts, one of which is converted into sulphur dioxide. The sulphur dioxide and the remaining hydrogen sulphide are then recombined in the presence of suitable catalysts and at a highly controlled temperature for a definite period of time. The contact time, sensitive temperature control, and catalytic action make this process an extremely delicate technological operation, although the chemical reaction involved is fairly simple. Difficulties encountered in coordinating these three factors to produce worthwhile yields had prevented earlier commercial production, although Southern Acid was the first to attempt this process on the North American Continent, which they did in 1887. The final product resulting from this process in the Mathieson plants is 99.97% pure sulphur, at present selling at a price of $3.85 per 100 pounds.[1] A plant working on the above mentioned method has produced as much as 300 long tons of pure sulphur a day, which when compared to the price that it sells for makes a sizable income for a plant of this type.

In the other process acid sludge remaining from the treatment of petroleum with sulphuric acid or alkylation acid, by-product from the alkylation method of producing high octane gasoline, may be used. The acid material is

1. Chemical and Engineering News, January 23, 1950.

fed into a vertical kiln containing a bed of glowing coke of fuel and is decomposed to yield the sulphur dioxide and coke, together with other gases. The coke formed from sludge is deposited on the coke bed, where some of it is used as fuel, and the remainder is removed as product.

The sulphur dioxide is then purified and reduced to sulphur through the use of hydrogen sulphide, other gases, or incandescent coke. Where both acid sludge and hydrogen sulphide are available at the same refinery, the hydrogen sulphide may be utilized in the acid sludge process. A feature of the process is that variations in feed may be readily handled and the sulphur dioxide to hydrogen sulphide ratio from the raw materials may vary widely without effecting recoveries.

7. The Wood Conservationist's Dream.[1]

Having discussed various methods of utilizing waste liquors of a chemical nature resulting from a number of manufacturing processes it may be of interest to note an example of the type of research that resulted in a completely new process as a result of the problem of waste disposal. The process at present being utilized at the Weyerhaeuser Timber Company of Longview, Washington, falls into this category as will be demonstrated by the history and development of the process as given below.

1. Chemical Engineering, December 1948; Business Week, December 18, 1948; Pulp and Paper, November 1948.

After ten long years of research, experiment and equipment development the month of October, 1948, saw the start up of a full-scale magnesia base process recovery plant which recovers heat and chemicals for operation of the sulphite mill of the Pulp Division of Weyerhaeuser at Longview, Washington.

In 1940 the Babcock & Wilcox Company and Howard Smith Paper Mills, Ltd., announced at the February, 1940, meeting of the Pulp and Paper Industry in New York the results of several years of joint experimental work and pilot plant operation on a cyclic process of treating sulphite pulp residual liquor involving the recovery of chemical in addition to the recovery of waste heat. The main departure from conventional practise was in the use of magnesium oxide in place of calcium oxide in the digesters to convert wood chips into sulphite pulp. This was based on the discovery by George H. Tomlinson, vice president of Howard Smith Paper Mills, Ltd., that magnesium, of all the chemical bases which might be considered for sulphite acid, is unique in that when a magnesium oxide base waste sulphite liquor is burned under specific conditions, sulphur dioxide is liberated and an ash can be produced containing highly reactive magnesium oxide free from magnesium sulphide. The sulphur dioxide can then be absorbed in a slurry of the revovered magnesium oxide, thus making possible a cyclic recovery process. Laboratory investigations showed results sufficiently promising to justify the installation in 1937 of a pilot plant at the Cornwall, Ontario, mill of Howard Smith Paper Mills, Ltd., as an intermediate step before undertaking the installation of a full scale commercial plant.

Meanwhile the Weyerhaeuser Timber Company had been investigating the possibilities of a magnesium oxide base sulphite acid, and a pilot plant was constructed and operated by Weyerhaeuser at Longview underthe supervision of the Pulp Division Research Department directed by R. S. Hatch. One commercial digester was operated for about a year with magnesium base acid with recovery obtained in a pilot plant furnace.

The common objectives of the companies involved in a development of this process and the desirability of eliminating any further duplication of effort soon lead to collaboration and the decision that the first full scale commercial mill would be installed by Weyerhaeuser at Longview. The decision to undertake this pioneering venture at considerable expense was in line with the progressive policy of the Weyerhaeuser management. Shortages of critical materials and the participation of the interested companies in the war effort considerably delayed the schedule for the new mill and it was not until 1946 that construction was begun.

The chemicals being recovered are magnesium oxide and sulphur dioxide, which are reused in the digesters of the Weyerhaeuser Timber Company's 275-ton bleached sulphite pulp mill at the Columbia River seaport. For the first time in the 81-year history of the bi-sulphite process magnesium oxide has been used exclusively in place of the traditional calcium lime.

But side by side with the recovery of these chemicals in the form of magnesium oxide dust and sulphur dioxide gas, is the production of heat and energy which supplies a large part of the necessary power for operation of the sulphite mill. These two goals are achieved in a seven-stage cylindrical process in which all waste cooking liquor is evaporated and burned and the risidual dust and gas is transformed again into a strong raw acid for reuse in cooking of chips.

Obviously, there are many tremendously important implications for the future of the sulphite pulp industry in this pioneering venture. It will be many months, if not years, before complete operating data is obtainable on the process, but Weyerhaeuser spokesmen have already estimated the savings of this process on their final product as $4.50 per ton of pulp produced. There are however, even at this early date, three major advantages to the magnesia base process which will be its major selling point in the future. They are firstly that the chemicals used in pulping are recovered for reuse, secondly that there is no waste liquor disposal problem, and thirdly that the heat energy produced supplies most of the electrical energy that runs the mill. The system also means greater use of wood products in that now the chips and waste wood that were normally needed for fuel to generate steam and power for the pulp mill go directly into pulp.

The advent of the magnesium bisulphite process has tremendous implications for the future of the sulphite pulp industry due to its outstanding economies and production techniques. As one technical journal put it, "The packing-house pig's unprocessed squeal is nothing compared with what happens at the Weyerhaeuser Timber Company's Longview, Washington, mill".[1]

1. Chemical and Engineering News, December 19, 1949.

CHAPTER VII

GREATER OPPORTUNITIES FOR LABOR

The examples given in the preceding chapters have shown that research was largely supported by management for its direct benefits to the plant or the industry as a whole. The number of industries that have been created or have been expanded through this research effort has given employment to many thousands of workers, and thus it can be seen that labor has benefited by research.

Figures of the Bureau of Labor Statistics show that the workers in the chemical industry receive a wage rate considerably above the average of other manufacturing industries. This may in part be explained by the fact that some chemical industries require very little manpower to run the plants and processes, and these few workers therefore have a high degree of respohsibility and are paid accordingly. On the other hand there are many industries, especially in the fields of plastics, fibers, and pulp and paper, where the labor situation is analogous to that of any average manufacturing establishment. (see Table 4)

Not only have the wages been higher, but the labor relations in all the chemical and process industries are very much better than those of the other manufacturing groups. Although the chemical and process industries produce 20% of this country's total of manufactured goods, the number of strikes occurring in those industries was less than 13% of

TABLE 4
WAGES OF INDUSTRIAL WORKERS

IN THE UNITED STATES

1947 and 1949

	Average Hourly Earnings		Average Weekly Wages	
	1947	Sept. 1949	1947	Sept. 1949
Industrial Inorganic Chemicals	$1.38	$1.595	$55.65	$64.12
All Manufacturing	$1.24	$1.407	$49.97	$55.72

Source: Chemical and Engineering News, January 2, 1950: pg. 13 (Based on Bureau of Labor Statistics Total Compensation Figures) the total occurring in the manufacturing industries, involving less than 7.5% of the workers in the latter category. This shows very dramatically that in order to obtain higher wages labor does not absolutely have to go out on strike against its employers. This fact is proven still further by the figures which to to show that within the last two years, with a strike record as shown above, the workers in the chemical and process industries have achieved a greater increase in wages than have the average of the manufacturing group as a whole. (see Table 5)

The worker in the chemical and process industries is one of the very few in his class whose field of application and usefulness has been continuously expanding in the past twenty years. This has been brought about partly by the rapid expansion of some industries through the increased demand for their products, and partly by the discovery of certain products and processes around which completely new industries have been built. Although a number of these have already been mentioned in connection with previous chapters it will do no harm to emphasize them at this point, and also to add a few cases which have not already been mentioned due to their relative unimportance.

The pulp industry in the South has been given a certain amount of publicity in this regard, as the processes for the utilization of southern pine and other woods has brought a new source of employment and income to the southern

TABLE 5
STRIKES IN THE UNITED STATES

FIRST SIX MONTHS, 1949.

	No. of Strikes	Workers Involved (Thousands)	Man Days Idle (Thousands)
All Industries	1,907	1,680	15,000
Manufacturing	864	472	6,160
Chemicals & Allied	39	11	191
Paper & Allied	20	7	233
Products of Petroleum and Coal	8	1	20
Leather & Products	39	12	185
Stone, Clay & Glass	29	6	46
Mining	255	946	5,450

Source: Chemical Engineering, February 1950; pg. 103

laborer. The latest development in this line is a new rayon pulp mill, the first in the world to use an entirely new process to produce dissolving wood pulp. For the first time hardwoods instead of softwoods will be used, and the rayon pulp will be made by the sulphate or kraft process instead of the traditional sulphite process.

The plant will start operation this year producing 300 tons a day or about 100,000 tons a year, and is being erected by the Southern Kraft Division of the International Paper Company.[1]

Since the end of World War 11, productive capacity of the rayon yarn and the cellophane industries in the United States has been increasing faster than the supply of dissolving woodpulps. When International gets its new plant in operation, it hopes to lift supply 16% above the output of woodpulp as produced in the beginning of 1949. The new process, developed by International's Southern Kraft Division with the help of Dr. Sigmund Wang and his staff of Industrial Cellulose Research, Ltd., combines novel methods of purification and bleaching to produce dissolving woodpulp for high-tenacity rayon yarns, cellophane, plastics and allied products. This new mill, merely by the quantity of its production rate and the employees it will engage will give the South's industrial and agricultural economy another much needed boost.

1. Chemical Engineering, December 1948.

While talking about the South it is well to mention the research being conducted on various uses for cotton and peanut protein, both of which are essentially enormous sources of raw materials for any future development. The major form this research is taking is in the use of these proteins to form fibers with special properties which can then be used by the textile industry, or the industry as a whole, in order to utilize these properties. Both these materials are by-products of two very important southern agricultural crops and therefore have the potentiality of being able to revive the industries connected with them.[1]

Before proceeding too far from the pulp and paper industry another reference should be made to the proposed pulp mill along the Colorado River which will be utilizing millions of cords of timber killed by beetles. This plant alone will increase the population of this sparsely populated area by an estimated eight thousand. The payroll of the plant would exceed $2 million a year and the effects of this alone on the standard of living in the area can well be imagined. These benefits to be derived from new industries are only a few examples taken from a large list which would of course include a large part of the plastics industry, most of the industry producing synthetic fibers, and many plants producing new chemicals.[2]

1. Chemical and Engineering News, February 13, 1950.
2. See page 118

In order to live up to their slogan of "Better things for better living . . . . through chemistry" the Du Pont Company employs a total of approximately three thousand technical and non-technical persons in their research divisions. The products that are produced as a result of the work of this research force go to make up a large part of the plastics industry of today and are the sole basis for the nylon industry, still a Du Pont monopoly. This latter product, employing a few thousand workers since its origin ten years ago, may be said to be giving employment to men that would otherwise, theoretically, be out of a job if nylon were not being produced at present. Similar research in many other companies has resulted in a 1300% increase in the production of plastics over the past ten years and a proportionate increase in the number of men employed in the industry.[1]

All the above facts go to show that while research is first and foremost a tool of industry to enable its various component parts to keep their place in competition between themselves, it is of major importance to the economy of the country as a whole in that it supplies jobs and wages for workers that would otherwise be out of work or have to be satisfied with a wage scale considerable below that which they are receiving at present.

1. Christian Science Monitor, September 21, 1948; Pamphlet of Modern Plastics, Inc.

CHAPTER VIII

RESEARCH AND NATURAL MATERIALS

Economically speaking this country is blessed with some of the world's greatest natural resources in the form of metals, oil, and wood and cotton. It has been America's greatest pride to be able to utilize this natural bounty in producing an industrial system that has no rival anywhere in the world. It must however be realized that production of goods from natural materials also has its drawbacks, and to meet some of these deficiencies research has been called upon to improve the qualities of the products made from these materials, to diversify their application and to find ways of assuring a continued supply of these materials to producers and consumers in the future. The last named topic was dealt with in part in Chapter VI, where research was demonstrated as being the means of assuring a continued supply of timber from the utilization of materials that would otherwise go to waste. This chapter, on the other hand, will attempt to illustrate the fields of research that are improving the properties of the natural materials, such as timber, wool, cotton and silk.

A. Improving Performance and Diversifying Application

The research being carried on in an effort to improve the performance of this country's natural materials in their various applications is endless. However, there are not too many of these that could legitimately be included under the heading of being research for the chemical and process industries, and it has therefore been found necessary to limit the number of examples to be covered by dividing them into two major fields. One of these is the impregnating of wood in order to preserve it from attack by the elements and by insects and organisms, while the other is concerned with the improvement of the characteristic properties of our every day fibers, mainly cotton and wool. As rayon and silk are so much alike they will be covered together and although rayon is a man-made fiber, for the purposes of this chapter it is being included with the other fibers due to the fact that next to cotton it is the next most important fiber. To facilitate the presentation of the results of research in this connection the chapter sub-titles will be designated by the trade name of the product that has been produced by this research and which imparts to the product the characteristics referred to therein.

1. Santophen 20[1]

Santophen 20 is the name the Monsanto Chemical Company has given to the chemical, pentachlorophenol - referred to in this article as Penta. The name pentachlorophenol comes from the two chemicals it is derived from, chlorine and phenol. These two materials, when chemically

1. Pamphlets of Monsanto Chemical Company, Organic Chemicals Division

combined are highly toxic to termites, Lyctus powder post beetles and wood destroying organisms.

Penta was first discovered in the University of Leipzig in 1841 by Otto Erdmann. As happens with many discoveries which are made as a by-product of another activity, Erdmann did not know the true structure of the product, and misnamed it. Furthermore, Penta was insignificant in the realms of chemistry till it was produced outside of the country of its origin, namely America.

In 1931 the Monsanto Chemical Company, interested in chlorinated chemicals, went to the Forest Products Laboratory at Madison, Wisconsin, to determine if the Division of Forest Pathology would be interested in testing some new chemicals as wood preservatives. Included in the group was one known as pentachlorophenol. The results of the biological tests conducted at that laboratory were presented before the American Wood-Preservers Association in 1932 and this paper may be looked upon as the first concrete step in the development of this important chemical. The work that was started then led to more and more study of the compound and others closely related to it. In 1935 another paper presented before the same Association compared a number of these compounds, but the true value of Penta was still not demonstrated although it was clearly indicated that it had potentialities as a wood preservative.

After proving in the laboratory that Penta protects wood, Monsanto research chemists went out of doors. In 1936 and 1937 these Monsanto chemists took some 4 x 4 Southern Pine posts and pressure treated them with Penta. They stuck the posts in test plots in Florida, Mississippi, and Louisiana, in soil that encourages intensive wood decay. The ground in these areas is infested with termites. Periodically, the treated posts were examined to find how well they were resisting attack. In 1948 - twelve years after they were first installed - all the posts were still in good condition. The Penta treatment which prevented the posts from rot was also found to protect the wood from termite attack. At the same time as the treated posts were set out, untreated posts were put in along with them. All the untreated posts became unserviceable within three years.

Meanwhile, industries working with wood began to recognize the value of Penta treatment. In this regard Penta entered the wood preservative field through the non-pressure application method. The first recognition came from the sash and door industry when the National Door Manufacturers Association set up a Preservative Standards Advisory Committee, whose function was to advise the Association on suitable preservatives for treating sash. In 1938, S. O. Hall, Secretary of the Association, announced the preservative minimum standard of the Association, and for the first time pentachlorophenol was an approved preservative. Today most sash and doors are Penta treated.

During the time this development was in progress, pole treaters were also studying the use of pentachlorophenol as a preservative for poles and crossarms. Reports from such companies as the Consolidated Treating Company and the Southern California Edison Company began to appear, and other pole treaters began to advertise poles treated by the non-pressure or pressure methods using Penta. As a result of the cooperation between treaters and the Bell Telephone Laboratories, various species of wood have been treated with Penta in petroleum oil.

The cleanliness of the Penta-treated poles has appealed to treaters and users as well as to linemen, and the use of Penta with creosote to give a greater protective power to wood thus treated, has caused Penta to grow in popularity with pole users to such an extent that in the United States in 1947 (the last time that such data was collected), over one fifth of the poles treated contained Penta either as the total active preservative or in combination with creosote, and this only a few years after its general acceptance by the industry. Such an acceptance cannot be attributed to sales effort alone, and the major producers of Penta and solutions thereof have been putting on an extensive campaign to interest the public in protecting wood, but to gain such ground a product must have considerable merit in itself.

It is essential to the wood preservation industry to recognize that there are many uses for treated wood, and that furthermore not all of the circumstances of use will make possible the treatment of wood at one or more of the commercial treating plants in the United States. In this line may be mentioned the field of railroad ties. Much work is now in progress on the selection of the best petroleum oils to use for such purposes, and there is no doubt that Penta will be used with creosote and creosote-petroleum mixtures in order to take advantage of the combined valuable properties of Penta and cresote.

An Illinois Agricultural Experiment Station survey in 1947 showed that approximately 500,000,000 wooden posts are needed each year in the United States, and that the U. S. Forest Service reports showed that slightly over seven million posts were treated in 1946. It must be recognized that there has been too great a neglect of this field when less that 1% of the posts during a nine-year period got treatment. These figures indicate clearly the potential field for preservatives for post treatment. Penta is admirably adapted to post preservation, for it can be applied in low viscosity oils by one of several treating methods with excellent absorption. These treating methods are self-explanatory and are: pressure treatment, hot-cold soak, cold soak treatment and brush treatment. There is no doubt that Penta in oil can be more easily handled and with better results, in the field of fence post protection, than can any other preservative in those cases where the services of a commercial treating plant are not at hand.

This somewhat abbreviated survey has already shown the multitude of uses to which Penta can be put. But there are many more fields which have not as yet been mentioned, such as lumber for construction purposes, bridge timbers, stringers and decking, highway guard rails, railroad car lumber, crossarms, and loading dock materials. In all these applications, Penta shows its many advantages, some of which stand out in comparison to other treating chemicals. The treatment is lasting under all conditions of weather and surroundings, the treated wood is clean and easily handled, it can be applied by numerous means which makes it possible for anyone to use, and most important of all, it is economical. Wood treated with Penta lasts at least twice as long, under any conditions, as untreated wood, and the small added cost of the actual treatment is little in comparison to having to replace the wood itself both in cost and time consumption.

The preservation of wood by the use of Penta can thus be seen to be doing management a considerable service. Not only is the manufacture of such a preservative an opportunity to start an entirely new industry, but it is also enabling management to use the lumber or timber from any one source for a greater period of time. The treated wood will be lasting at least twice as long as the wood utilized previously which was untreated, thus necessitating less than half the replacement that had previously been required. This effect will be felt to the utmost in the industries using large quantities of wood outdoors, such as the railroads, utilities, and mines, besides the farmer who depends for all his fencing and building material on the lumber industry. The total consumption of wood by these users runs into many billions of board feet annually.

2. Santobrite[1]

As early as 1932, Monsanto Chemical Company studied the chlorinated phenols. Pentachlorophenol (Penta - Santophen) and its sodium salt were found to be outstanding preservatives, and the former of the two above named compounds was discussed in some detail in the previous pages. Sodium pentachlorophenate was first manufactured on a commercial scale by Monsanto in 1936 and marketed underthe trade name of Santobrite. Because of its demonstrated effectiveness in biological control and its many desirable physical properties, combined with low cost and availability, this chemical is serving usefully in many and varied industries.

Most industrial products of organic origin are subject to microbiological attack at some stage in their preparation or use. Materials which thus require preservation include wood, cellulosic products, textiles, starches, adhesives, proteins, leather, oils, paints, latex and rubber. Equally important applications are termite control in wood

1. Pamphlets of Monsanto Chemical Company, Organic Chemicals Division.

and insulating board (covered previously), the control of slime and algae, the manufacture of herbicides and as a fermentation disenfectant.

For the purpose of this analysis the uses of Santobrite are restricted to its effect in four industries, namely that of adhesives, the pulp and paper industry, that of rubber latex and the control of slime and algae in cooling systems.

a. Adhesives.

The old idea that only substances of a gelatinous character have adhesive properties has long been discarded. It has been demonstrated that strong joints can be obtained with any liquid material which will "wet" both surfaces to be joined and become solid in place. This concept has been well demonstrated by the variety of materials now used in preparing adhesives, the more important of which are animal and fish by-products, starches and dextrines, latex, casein, blood, gums, resins, and cellulose esters and ethers. It is these new adhesive raw materials that have brought with them the problems of biological decomposition.

Experience has clearly demonstrated that in most adhesives there is need for a preservative to protect the aqueous solutions and suspensions against biological deterioration. Materials such as zinc sulphate, formaldehyde, and beta-naphthol have been used, but none of these is fully satisfactory with respect to effectiveness and permanence.

The organisms to be combatted are numerous and varied in type, ranging from the fungi, bacteria and yeasts which attack starches and reduce them to sugars, alcohols, and acids, to the putrefaction bacteria which reduce proteinaceous glues to mercaptans, amines, hydrogen sulphide, and other evil-smelling compounds.

Santobrite for the preservation of adhesives has been carefully investigated. Its effectiveness in combatting the organisms which attack adhesives has been determined by laboratory tests under severe conditions, and although the data is available it will not be presented here for the interest of brevity.

b. Pulp and Paper Industry.

Microbiological activity serves no useful purpose in any of the processes of pulp and paper manufacturing. To the contrary, such activity gives rise to a number of operating difficulties and serious economic problem.

It would be difficult, indeed, to establish the money value of the losses caused by slime spots and breaks, blinded wires and plugged felts, obstructed stock and water lines, and stock losses due to biological decomposition. However, it is generally agreed that such losses may seriously impair the margin of profit and even eliminate it entirely in some cases.

Pulp and paper systems from grinder or wash pit to finished lap or sheet furnish a fertile field for microbiological activity, because the environments are favorable with respect to the controlling factors, mainly, food supply, moisture, air tension, temperature, light, and chemical reaction. Moisture relationships are, perhaps, the most important factors influencing the type of growth and are chiefly responsible for the differences in microbiological flora at different points in the system.

Thus, where an excess of water is present, bacterial growth is most abundant, and, as is well known, bacterial slimes are found in those parts of the system which are completely submerged, or nearly so. The same type of growth, namely bacterial, is principally responsible for the fermentation and putrifaction of pulp slurry and settling-tank sludge and for the rotting of felts.

Fungi, on the other hand, cannot grow when completely submerged but prefer a moist, not excessively wet environment, such as is presented by green pulp logs in the pile, stored lap pulp, or spatter on the walls of tanks. Rotting, staining, specking, and sliming of pulp stored damp are caused by fungi, as is also the mildewing of paper board products and coated papers.

Other types of microorganisms, such as yeasts, algae, and protozoa are also found occasionally in slimes and other paper mill flora, but are really of causative significance.

It has been the general practise to combat slime by good housekeeping involving regular cleanouts. Many mills supplement such measures with continuous anti-slime treatments. Slime formation in pulp and paper systems is often prevented or greatly reduced by the application of chlorine or chlorine with ammonia in varying amounts to the fresh water supply, the shower water, or the white water, and sometimes by treatment at all of these places.

Chlorine is a highly effective bactericide (and a somewhat less effective fungicide), but its usefulness is limited by its extreme reactivity with organic matter, which causes the toxic chemical to become spent quickly. The use of ammonia with chlorine in various ratios reduces the oxidation potential of the chlorine and thus prolongs, somewhat, the interval of toxic efficacy. However, satisfactore control of slime by the use of chlorine with or without ammonia is found difficult under some conditions, and these chemicals have little value in the solution of other microbiological problems of the pulp and paper industry.

Copper sulphate, zinc sulphate, and combinations of chlorine with copper sulphate and ammonia are sometimes used to combat slime, but the results achieved are not consistently satisfactory. Organomercurial compounds have been effective for certain applications.

Mill experience has confirmed the results of laboratory experiments demonstrating the effectiveness of Santobrite for the control of paper mill organisms.

Chemically stable, non-corrosive to metals, non-volatile, practically odorless, Santobrite is well suited to the processes of manufacture and the requirements of the finished product.

c. Treatment of Cooling Water Systems.

Algae and slime-forming organisms grow luxuriantly in many industrial water systems where they tend to clog water passages and form adherent, insulating deposits resulting in serious impairment of efficiency and capacity. The magnitude of this problem has grown rapidly in recent years by reason of the great increase in the use of recirculating, cooling-water systems.

The elimination of accumulated slime and algae can be, and frequently is, accomplished by mechanically cleaning the system periodically. Continuous supression of micro-organism growth to prevent its development and attachment to heat-transfer surfaces can best be achieved by chemical treatment of the water. Copper sulphate, sulphuric acid, potassium permanganate, chlorine, chloramine, combinations of copper sulphate with organic compounds and with chlorine have been used. All of these have value and can be used effectively under suitable conditions. However, none of them is a panacea for cooling-water organism troubles and, too often, it is found in specific instances, that none is satisfactory from the standpoint of effectiveness, cost and practicability.

With the understanding that a good industrial slime and algae control agent must meet many requirements besides toxicity to microorganisms, Monsanto investigated the usefulness of a great many organic and inorganic materials believed to be of possible value. Santobrite was found to be the product of outstanding merit and the experimental data on which its industrial application was launched in 1937 have been confirmed by the subsequent experience of hundreds of cooling-water plants. Santobrite is highly toxic to algae and slime forming organisms, it is non corrosive to metals, it is compatible with other chemical treatments given cooling water, and it is easily applied as there is no special feeding equipment required and the product is packed to facilitate its handling and application.

d. Latex Transportation.

Latex, though known for centuries in its native state, did not become a significant article of commerce until 1920. The demand for it did not increase greatly for several years following that time and not until scientific research developed ways and means of handling the latex and applying it to diversified products. The importance of latex in industry just before the World War can be judged by the importation into the United States in 1937 of 51,000,000 pounds.

A high percentage of the world's productive area for rubber is concentrated in tropical countries and the collection of latex is from millions of trees spread over hundreds of thousands of acres. With ultimate shipment of the latex to points far distant from the source, the need for an effective preservative becomes apparent. The previous search for preservatives included experimentation with ammonia, formaldehyde, phenol, mercuric chloride, tannic and boric acids, sodium bisulphite and other chemicals. Ammonia until recently had been considered the most satisfactory, from the standpoint of effectiveness at moderate cost. However, ammonia when used alone produces latex possessing numerous undesirable properties, such as the development of unpleasant odors in the latex due to the volatility of ammonia, the accentuating of "webbing" in goods that are produced by the dip process, and the odor imparted to the latex itself by the use of ammonia.

Dr. Edgar Rhodes, while directing research at Kuala Lumpur for the Chemical Division of the Rubber Research Institute of Malaya, determined the preservative properties of Santobrite together with those of other chemicals. The results of this work are summarized in his report published in the Journal of the Rubber Research Institute of Malaya, 1938, in which he gives "certain requirements" for judging the efficacy of preservatives and later states, "Sodium Pentachlorophenate (Santobrite) is the first disinfectant which does appear to satisgy them reasonably well".

The four major uses for Santobrite mentioned above will show without a doubt the service that this chemical is giving to management in the chemical and process industries. In addition to its obvious chemical characteristics which have been mentioned in some detail the cost of Santobrite treatment is relatively low, varying of course with the design and operating characteristics of the system in which it is being applied. It is effective in low concentrations, convenient to handle, non-volatile at normal temperatures, comparatively odorless, effective and permanent.

3. Resloom[1]

With this chemical the field of textile fibers is entered and as will be shown by examples in this and subsequent chemicals there is much that can be done with our everyday materials that will make them more useful and better in all ways that concern the selling of a product on the market.

Resloom is a low polymer or water soluble "resin former" that imparts stabilization, resilience, durability, and shrinkage control to all types of textile fabrics without impairing the original fiber characteristics. Washable woolens, crush resistant, and stabilized synthetics and muss-resistant cottons which cannot be secured by alterations in weaving, fabric construction or in any other way, are readily obtained by Resloom treatment.

Shrinkage control is one of the most unique achievements of Resloom. Repeated launderings can be performed on

1. Pamphlet of Monsanto Chemical Company, Textile Department (see Bibliography)

the treated goods without resulting in felting, pilling, or distortion. On one test, a Resloom-treated wool flannel shirt shrank less than 1½% after five trips through a soap and water laundry. Under the same treatment an untreated shirt used as a control sample shrank to 50% of its original size. Wool flannel treated with Resloom has a very soft, smooth hand with excellent stability. The elasticity, softness and stability of the Resloom finish is retained after many washings.

By combining proper fabric construction and Resloom treatment, a lighter weight, more porous and thus cooler fabric can be woven, thus opening new opportunities for the use of wool for summer garments. The treated wool retains all the properties that make it desirable for use in garments - crush resistance, strength, and stability - and Resloom has in this way opened up a new field for the textile industry.

In the case of rayon, Resloom imparts better seam strength and slippage control, and produces cooler, quicker-drying, dimensionally stable fabrics that hold their shape and do not soil. Silk, which is customarily weighted with tin salts, may have its natural fine properties enhanced instead with a stabilizing resin (Resloom) that will preserve the fabric's beauty.

Truly long lasting, muss-resistant cottons, whose finish is unaffected by wear, washing or dry cleaning, can be produced with Resloom. Neat, crisp, wrinkle resistant summer wear and a durable glaze finish can be fashioned by fusing Resloom into the heart of the cotton fiber by the Everglaze process.

Mixtures or blends of various natural and synthetic fibers may create problems in finishing, but with the correct Resloom product for the finish desired there is no difficulty in the production of stabilized crush resistant finishes.

An enumeration of the properties imparted to fabrics by the application of Resloom would include the following: reduces extent of shrinkage from 75-100%; increases the resilience of worsted fabrics; yields fast shades in dyeing; permanently improves the body and fullness of the fabric; controls slippage of filament yarns; eliminates pilling on laundering of woolen goods; reduces tendency of wool to felt after laundering; yields soft, wooly finishes; produces cooler, quick-drying, more stable fabrics that hold their shape and do not soil. Only a small fraction of the above list is enough to make a considerable impression on the textile industry and in its totality there is no doube that Resloom will have a considerable effect on the utilization of all the textile fabrics being produced at present.

4. Swellable Cotton Fibers[1]

A promising approach to the problem of increasing the usefulness of cotton is the chemical modification of the

1. Pamphlets of Southern Regional Research Laboratory

cotton after its manufacturing into yarn or cloth, while at the same time preserving its fibrous nature. A notable example of this is the partial acetylation of cotton to yield a cloth or thread which is very resistant to rotting. In the case under discussion however the object was to prepare a highly swellable cotton so that the permeability of the cloth to water would be decreased.

The fabrics known as Shirley cloths are especially woven to make them permeable to air when dry but only slightly permeable to water when damp. This property is due to the decrease of space between the fibers as well as that between the yarns by virtue of the swelling of the fibers and is enhanced by the construction of the fabric. It has long been known that linen fibers swell quickly on exposure to water, and for this reason linen is used for fire hose. The shortage of linen during the war prompted C. F. Goldthwait to substitute treated cotton for linen. The cotton was impregnated with hydroxyethyl ether of cellulose to a take-up of about 6%. The ether, although insoluble in water, swelled quickly on exposure to water and made a cotton fire hose watertight. J. W. Stallings recently patented the treatment of cellulosic fibers with acrylonitrile in the presence of sodium hydroxide to make lead-resistant, fireproof fire hose.

Research in this field as carried out by the Southern Regional Research Laboratory, New Orleans, Louisiana, has found out that a quickly swellable cotton fiber may be obtained by partial carboxymethylation to such a degree of substitution that the fiber does not lose strength but does swell when wet. Such carboxymethylation is obtained by the impregnation of cellulose with a solution of monochloroacetic acid followed by a treatment with a strong solution of sodium hydroxide yielding the sodium salt of carboxymethylcellulose.

The treated yarns do not vary greatly in breaking strength, feel, appearance, or moisture content from mercerized controls. Swelling capacity and water retention, however, are greatly increased. The treated cotton shows different dyeing characteristics from untreated cotton. Although the addition of small amounts of carboxymethyl group to the cellulose molecule does not protect it from microbiological attack, addition of copper, silver, or mercury, to form the corresponding insoluble salt of carboxymethylcellulose, imparts considerable resistance to such attack.

The applications for a product as that produced by the above outlined process are numerous and are not restricted to fire hoses and similar products. If this research could be continued and perfected, swellable cotton fibers could be used in many products which are at present requiring two or three different materials to achieve the same result.

5. Erifon[1]

Of all the improvements that could be made in any textile fiber or fabric that ranking first consideration with most people is the matter of flammability. In this regard a simple treatment to make cotton and rayon fabrics, which make up 89% of the textile fiber consumption in the United States,[2] resistant to fire and flame has been the goal of scientists and research workers for years. The use of flame resistant fabrics for clothing, draperies, awning, and upholstery would greatly reduce the loss of life and property from fire. On this topic a member of the Textile Resin Department of the American Cyanamid Company, Mr. K. H. Barnard, has indicated that an annual market of 100,000,000 pounds of fabric awaits the development of an effective but inexpensive flame-retarding process.[3] At the present market price of Du Pont's new flame retardant, Erifon, this would amount to a total requirement of 100,000,000 pounds of Erifon and support an industry with sales worth $30,000,000.

Although it is doubtful if cotton and rayan fibers and fabrics can ever be made "fireproof" as are the glass (Fiberglas) and asbestos fibers, they can be made

1. Pamphlet of Du Pont Company, Pigments Department; Chemical Engineering, November 1949.
2. Memorandum of the Rayon Industry by Morgan Stanley & Company.
3. Chemical Engineering, March 1950

flame resistant, which may be defined as not continuing to support combustion or being consumed by afterglow when the source of ignition is removed after first having been ignited by flame. A flame retardant is a substance which when properly applied slows down the rate of combustion of a flammable material, or renders the material incapable of supporting combustion.

In the course of many research studies of cellulose fibers, Du Pont chemists learned that certain inorganic salts, mainly the salts of titanium and antimony, appeared to react with the cellulose molecule. After such reactions had taken place the fiber remained, for all practical purposes, unchanged, but the ability of the fiber to support combustion was materially lowered. Erifon flame retardant is an aqueous solution of these inorganic salts containing free hydrochloric acid. It is in no sense a coating, contains no oil, resin or other organic, film-forming materials. Consequently, when properly applied to cellulose fibers such as cotton and rayon, Erifon reacts with the cellulose molecule changint it chemically but not physically. Neutralization with suitable alkali is necessary in insolubilize the compound and thorough scrubbing is necessary to remove the excess reactants and by-products of the reaction. The result is a flame resistance incorporated as an integral part of the fiber. Due to this fact the resistance will be maintained after repeated household laundering, dry cleaning and exposure to weather.

In addition to the characteristics already mentioned, Erifon is non-toxic and non-irritating to the skin, does not materially change such properties as "hand", porosity and texture, and adds little weight to the fabric it is applied to. Application of Erifon can be carried out only by textile mills in connection with other manufacturing processes and before the fabrics are made into clothing or other articles. Although it cannot be applied in the home or laundry and dry cleaning establishments, it can be applied by conventional textile mill equipment.

Fabrics treated with Erifon will char when exposed to flame, but will not support combustion when the flame is removed, and this fact has enabled it to exceed the requirements of the flameproofing tests established by the Federal Government and private research organizations. This is its major selling point but it is also of interest to know the approximate cost of applying Erifon to cloth of various types and weights. Taking an average weight sheeting, that of four ounces, the total raw materials and application costs amount to approximately 7.4 cents per yard, which by all standards of measurement must be said to be very reasonable.

CHAPTER IX

RESEARCH SUPPLEMENTS NATURAL RESOURCES

As mentioned previously, of all this country's natural resources that of petroleum has been given the greatest amount of publicity during the past few years. Mention has been made continuously of the coming scarcity of petroleum because of the rate at which it is being consumed at present, and that "something must be done about it". In order to illustrate the fact that the time has not yet come when this country will be left without petroleum, and that while all the talk about action is going on that both the Federal government and the oil industry are conducting tremendous research and development programs, this discussion is devoted largely to the research and results obtained from a study of natural gas, coal and oil shale as possible sources of liquid fuels. A late arrival in this phase of research has been the discovery of a method of manufacturing synthetic mica which will be discussed in a short summary of the research and process towards the end of this chapter.

1. Synthetic Fuels.[1]

The magnitude of effort concentrated on synthetic fuels may in part be judged from research expenditures. The Bureau of Mines has been working on a $30,000,000 program

1. Pamphlets of Standard Oil Development Company and the United States Department of the Interior. (see Bibliography)

of research into coal hydrogenation, Fischer-Tropsch synthesis, as well as oil-shale mining and processing, and legislation has just been approved by Congress to extend the original appropriation to $60,000,000.

Standard Oil Company (N.J.) has been very active in this field for many years. Some twenty years ago it started a $10,000,000 development program on hydrogenation of oil and coal. In addition, large oil-hydrogenation plants were erected and operated for a number of years. Later, work was started on development of the hydrocarbon-synthesis process, a modification and appreciable improvement of the German Fischer-Tropsch process, for making gasoline from natural gas and coal, but was discontinued during the war years. In 1945 work on the hydrocarbon-synthesis process was resumed and up to the present about $10,000,000 has been spent on this development. In addition, considerable work has been carried out by the Jersey group on retorting of oil shales.

Vigorous research programs on synthetic fuels have also been carried out by other oil companies. Last year, for example, it is estimated that the oil industry spent in excess of $10,000,000 on such research.

The extensive research effor, briefly outlined above, arrises from the problem of meeting the country's expanding needs for oil products. One phase of this problem is to meet the needs for normal peacetime consumption, which, based on the present rate of increase, will be growing at the rate of around 75,000,000 barrels of oil products per year. It is expected that the oil industry can and will meet this expanding demand through the installation of crude oil producing and refining facilities and through the installation of synthetic oil capacity where economical. A second phase of the oil supply problem is to make available supplies for military use in case of national emergency.

Proven reserves of crude oil are currently estimated slightly in excess of 23 billion barrels. This is the highest level ever reached in the United States. Statistics on proven reserves and production indicate that such reserves have, by and large, maintained about the same relationship to production. For instance, since 1935 the proven reserves as reported from year to year have remained at a level of about twelve of fifteen years supply. The current proven reserves are essentially at this level.

Cumulative production of crude oil since the start of the United States oil industry is about 35 billion barrels, which, when added to the current proven reserves, totals about 58 billion barrels of oil which has been found. Potential reserves yet to be found cannot, of course, be definitely predicted. However, based on geological reports of favorable sedementary rock formations yet unexplored, it appears reasonable to believe that at least as much oil remains to be found in the United States as has been found to date. The cost for crude oil production, however, has been increasing and it is possible that synthetic oil capacity on a large scale will in time become competitive with liquid fuels produced from petroleum.

a. Natural Gas.

Natural gas is one of the most interesting materials which may be used for producing synthetic fuels, although it is limited in availability. The known natural gas reserves in the United States are currently estimated to be about 170 trillion cubic feet. If this were all converted to oil, it would be equivalent of about 16 billion barrels of oil, which is about 70% of the known oil reserves. The rate of discovery and extension of known reserves of natural gas averaged about 8 trillion cubic feet per year for the fifteen year period ending in 1945. Discoveries and extensions of known reserves for 1946 are about 13 trillion cubic feet, and about 14 trillion cubic feet for 1947. Due to deeper drilling for oil, the trend is to find more gas relative to oil. It is believed reasonable, therefore, to assume a rate for extension of known reserves and new discoveries for the next few years of 10 trillion cubic feet per year.

Present consumption of natural gas for purposes other than carbon black, field use, and loss, is about 2.7 trillion cubic feet per year. Based on present usage, an estimate has been made of the gas that will be required in the future for carbon black, field use, and loss, amounting to 1.6 trillion cubic feet per year. This latter figure does not represent exactly pres nt-day conditions, as certain improvement in loss of gas are pictured. This quantity, when added to present day consumption for industrial use and heating, gives a total of 4.3 trillion cubic feet.

New pipe-line capacity has been authorized or applied for, amounting to 1.8 trillion cubic feet per year. Assuming all these pipe lines are installed, the consumption of natural gas would then be brought up to about 6.1 trillion cubic feet per year. On the assumption that the rate of discoveries and extensions would be 10 trillion cubic feet per year, there would then be available, without drawing on reserves, for either further pipe line and industrial use of for synthesis, about 3.9 trillion cubic feet of natural gas. When making still further allowance for increased industrial and heating use, it is believed that there will be enough natural gas supplies to produce at least some 500,000 barrels per day of oil products.

There are two main steps in the process of producing synthetic fuels from natural gas. In the first step, a deficiency of 95% purity oxygen, prepared by liquefaction and distillation of air, is contacted with natural gas at elevated pressure and temperature to produce synthesis gas consisting essentially of hydrogen and carbon monoxide. The gas, after cooling and scrubbing, then flows to the second or synthesis step.

In the synthesis reactors the gas is contacted with finely divided iron-type catalyst maintained as a fluid solids bed and the gases react to form mainly a mixture of hydrocarbons and some oxygenated chemicals, mostly alcohols. Upon cooling and oil scrubbing, there is separated raw hydrocarbon oil, containing essentially 90% gasoline and 10% gas oil, plus a water layer containing dissolved oxygenated chemicals.

The raw products are then processed to produce marketable materials. Synthesis gasoline is of particular interest since its octane number will exceed present premium grade gasoline and will, with some added lead, satisfy a 10:1 compression ratio engine which is capable of giving about 30% more miles per gallon than present day engines.

The natural gas hydrocarbon-synthesis process has been well worked out on an experimental and pilot scale, and two commerical plants of about 7,000 barrels per day capacity each are at present operating under the watchful eye of the oil industry.

b. Coal.

The United States reserves of coal, including lignite, are estimated to be very large based on estimates prepared by the United States Geological Survey. These indicate that the reserve of coal in place amounts to about 3,200 billion tons. This is essentially equal to 2,500

billion tons of equivalent bituminous coal quality. Of this amount, on a heating-value basis, about two thirds is west of the Mississippi River. The present consumption of coal in the United States is estimated at about 0.6 billion tons per year and it can be seen from these figures that the estimated reserves are very large compared to the billion tons of equivalent bituminous coal quality. Of this amount, on a heating-value basis, about two thirds is west of the Mississippi River. The present consumption of coal in the United States is estimated at about 0.6 billion tons per year and it can be seen from these figures that the estimated reserves are very large compared to the consumption.

Consumption of oil products in the United States is increasing and may reach seven million barrels per day in the near future. If all of these products were supplied from coal, assuming a coal consumption of a half ton per barrel, the coal requirement would be about 1.3 billion tons per year.

There are, therefore, enough indicated coal reserves to supply the country's need for both coal as such, and in addition, coal for making all of the oil requirements for about the next thousand years. Appreciable revision of these reserves will undoubtedly be required when considering only coal that can be mined at reasonable cost and at locations where the erection of synthetic-oil plants would be advantageous. Much of the coal is west of the Mississippi River and here water supply for synthetic-oil plants would be a very pressing problem. A much more detailed analysis would be required to determine the real possibilities from a quantity standpoint on production of oil from coal, taking into consideration water supplies and other factors.

The hydrocarbon-synthesis method of converting coal into oil products is very similar to the process described for natural gas. As in the case where natural gas is used as the raw material, it is essentially a two-step process, involving first the preparation of a synthesis gas, and second, its reaction over a catalyst. In this case, however, the gasification of coal to produce synthesis gas is accomplished with oxygen and steam. In addition, the raw synthesis gas produced from coal must be purified before entering the synthesis reactors. The synthesis reaction system, product recovery, separation, and treating steps are essentially the same for both raw materials.

Due to the difference between natural gas and coal as a raw material, the preperation of synthesis gas from coal is also quite different in terms of equipment from that required for natural gas. Considerable work was carried out in Germany on the production of synthesis gas from coal by continuous process methods as contrasted to the intermittent type of process that has been widely used for synthesis of water-gas manufacture. The gas-making processes developed in Germany had particular application to noncaking coals and do represent improvement over the discontinuous process.

It is believed that still further improvements can be made in the continuous production of synthesis gas from coal and considerable work along this line is now being carried out in this country. Certain of the processes being investigated are expected to handle caking coals equally as well as noncaking coals. It is felt that this development will lead to methods more economical than those developed in Germany. From a technical standpoint, therefore, the main step to be worked out for the conversion of coal to oil using the general principle of the hydrocarbon synthesis process is to get an improved method of making synthesis gas from coal. The cooperative research program between Pittsburgh Consolidation Coal Company and Standard Oil Development Company is vigorously pursuing this project and is at present operating a plant bases on this work at Imperial, Pennsylvania.

An alternate method of producing oil products from coal is by the hydrogenation process. This process was extensively exploited in Germany and there is a large commercial plant located in England. Detailed information is now available on the experience in commercial plants on hydrogenating coal in both countries. The United States Bureau of Mines has completed the construction and is now putting into operation a plant to produce 200-300 barrels per day of oil and gasoline from coal by hydrogenation. This plant is situated in Louisiana, Missouri, and, based on the experience available to date from the design and construction of the demonstration plant there, the Bureau has recently completed a detailed estimate of the initial cost, requirements, and operating costs of a 30,000 barrel a day coal hydrogenation plant. In the interest of brevity the multitude of figures on construction costs, costs of raw materials, labor and management, are omitted here and the only figure that is given is that which effects the consumer the most, that of the price of gasoline. The manufacturing costs per gallon of gasoline by this process utilizing two different types of bituminous coal are 8.0 and 10.2 cents respectively, which compares very favorably with the market price of today's gasoline from petroleum which varies between 10.5 and 11.5 cents per gallon.

c. Oil Shale.

Shale deposits in the United States are quite large. The approximate deposits, exclusive of tar sands and gilsonite, posess an estimated recoverable quantity of shale oil of 250,310 million barrels. The Green River formation of northwestern Colorado appears to be the major oil-shale deposit in the United States and it is indicated to be at least 500 feet thick. Within this deposit there appear to be minable beds 70 to 90 feet thick, having an average oil yield of thirty gallons per ton. This formation is reported to cover an area of approximately 1,000 square miles. The Bureau of Mines project at Rifle, Colorado, is concerned with developing, mining and processing methods for the 70 to 90 feet thickness of rick oil shale.

After making allowance for the shale which must be left underground for supporting pillars in the Bureau of

Mines quarry method of mining, with the latest and largest mechanical equipment available, it would appear that the 70 to 90 foot bed of Colorado shale alone would yield the equivalent of 75 to 90 billion barrels of recoverable oil. This richness of oil shale has been considered in the present study, although at least an equal quantity of reserves appears to exist in Colorado at richness of about fifteen gallons per ton. There are also substantial deposits of oil shale in other states. For processing this material, particularly in Colorado and other western states, water supply would be a major factor in determining the rate at which the shale can be produced.

The organic matter in oil shale breaks down and distills when shale is heated in the range of 800° to 1,000°F. One of the problems in using shale has been a cheap method of carrying out the heating or retorting. In the last few years, largely as an outgrowth of developments on catalytic cracking of oil, some new processes for retorting of shale have been proposed and at least partially demonstrated which appear to offer considerable improvement over older processes.

The shale, after crushing, is fed to the retorting vessel of the two-vessel system operating on the fluidized solids principle. Heat for retorting is supplied by withdrawing shale from the reactor to the burner. In the latter vessel a portion of the residual carbonaceous material on the spent shale is burned with air, thus heating the spent shale above the retorting temperature. The heated spent shale is then circulated back to the reactor.

This process, like other oil shale retorting processes, yields a rather heavy product of disagreeable odor. The product so obtained is transported by pipe line to a refinery where the raw shale oil is hydrogenated to a quality equivalent to crude oil and then processed into gasoline using conventional refining techniques.

Retorting of Colorado oil shales by the process described has been successfully demonstrated in small pilot plants. On a larger scale the Standard Oil Development Company has reconstructed its fluid-catalyst-cracking pilot plant at Baton Rouge, Louisiana, to process oil shale, and tests are being made. The shale oil for this study is being supplied by the Bureau of Mines and their representatives are also observing the tests being conducted.

Estimates for oil shale operations have been made for a large plant to produce about 100,000 barrels of oil a day. The only economical way to transport shale oil from the Rocky Mountains to the major consuming centers is by pipe-line and its construction could be justified only if considerable plant capacity is contemplated. Assuming a reasonable schedule for delivery of equipment and a satisfactory labor supply, initial production could begin in two years and full production could be attained in three years.

The initial investment in the entire plant will approximate 409,000,000 dollars which amounts to 4,090 dollars per barrel of oil per day. There is a good possibility that in actual practice this figure as estimated by the Bureau of Mines can be considerably reduced. To produce shale oil the operating costs are about $1.29 per ton of shale or approximately $2.00 per barrel of crude shale oil. Assuming a 75% yield through the refinery the final product will cost about $3.50 per barrel or an average of 8.4 cents per gallon. Even under the assumption that large parts of this may be heating oil and diesel fuel the price still compares very favorably with that of gasoline from petroleum which ranges from 10.5 to 11.5 cents per gallon.

The petroleum industry, probably the most vital part of the chemical and process industries, is not only a direct source of fuel and power and the form of gasoline and fuel oils, but is also at present the most important supplier of chemical intermediates. Not only has it been proved over and over again that oil is a more stable and economical source of heat and power than coal, but in the past decade the vagaries of the mine workers and their dictatorial president has made the price of coal even higher and its supply less reliable. Chapter IV went into some detail to show to what extent oil was an absolute necessity in the economy of this country today, and the remainder of the work has brought this fact our further.

The size and importance of the chemical industry can be further estimated from the percentage of the national income that is derived from it and the numerous subsidiary industries that it feeds with raw materials. The chemical and process industries, the largest individual manufacturing group within the nation's manufacturing industries, comprises 20.4% of the national income, the all-manufacturing total for this country making up a total of 30.5% of the national income. Of this, 9.7% of the national income, again the largest portion within the chemical and process industries, is made up by the petroleum, coal and chemical companies. This coal, it must be remembered, is only that used as a source of raw materials for intermediates in the manufacture of chemicals, and, as has been mentioned previously, a large number of these uses have been taken over by petroleum. As petroleum is at the present time undeniably the major chemical intermediate, the field of chemicals can be said to be largely derived from the petroleum industry. From this analysis it can be seen that research on the manufacture of synthetic fuels is supporting the source of nearly 10% of this country's national income.[1]

1. Chemical Engineering, February 1949

2. Synthetic Mica[1]

The first month of the mid-century, January 1950, saw the successful synthesis of mica by scientists of the National Bureau of Standards under the spondorship of the Office of Naval Research.

Mica is a critical material in the manufacture of electrical and electronics equipment, and the synthetic mica produced has essentially the same properties as natural mica but is superior to the natural substance in its ability to withstand high temperatures.

The process itself involves the combination of four ingredients, three of which are the common materials sometimes used in making glass: quartz, magnesite and bauxite. The fourth - a fluorosilicate compound - is added because it acts as a crystallyzing agent and makes it possible to produce mica at normal atmospheric pressure whereas in nature it is only produced under extremely high temperatures and pressures. It is this fourth ingredient which makes the synthetic mica superior to the natural product.

The importance of this discovery and the demand for the product is ably illustrated in a statement made by the Secretary of Commerce, Charles Sawyer:

> This discovery is of immense importance to the United States, which is the world's largest consumer of mica but which produces only enough to meet a fraction of its own requirements. During 1948 the United States imported over 10,000 tons

1. Chemical Engineering, February 1950

of high grade mica valued at more than
$15 million. In the same period, domestic production of high grade mica totalled only 135 tons with a value of less than $50,000. Synthetic mica production may make it possible for the United States to meet its own demands for this critical material.

CHAPTER X

CONVERSION OF WAR RESEARCH

The five years between 1941 and 1946 saw one of the greatest research programs in the history of industry bent towards one object, the furtherance and completion of a war of destruction against other nations. During this time the Federal Government spent an average of $500 million a year on research, excluding atomic research which alone was spending upto a million dollars a day towards the end of the war and had reached the stupendous sum of expenditures of three billion dollars by the end of 1947. Excluding atomic research, Federal expenditures on research amounted to approximately $100 million a year more than was being spent by private industry, universities and research institutes combined. Before the war government money accounted for only one sixth of the nation's research bill which rose to an average of 83% during the five years of the war. This figure has by now been somewhat readjusted, not by government spending less which it is not doing, but by the increased expenditure for research in industry which is now spending over $450 million a year, bringing its part of the research budget from a low of 13% during the war to 39%, which in its turn has lowered the position of the government to expending only 54% of the total research budget.[1]

1. Chemical and Engineering News, February 6, 1950.

These Federal Government research expenditures have been incorrectly dubbed as military expenditures. No research can be purely military, just as any peace time research cannot be classified as being perfectly non-military. The automobile, which was developed in peacetime was an essential vehicle in the last war, as were also gasoline, airplanes, radios and many other standard items of modern living. On the other hand, developments which were originally "purely" for war purposes have already been integrated into the peacetime economy. It is the purpose of this chapter to show some of these conversions from war-to peace-time application as they effect the chemical and process industries and the consumers they serve.

It would be well, at this time, to dwell upon a statement made by Dr. Frederick E. Terman, Dean of the Stanford University School of Engineering, shortly after the cessation of hostilities:

> We have learned through the war experience that money spent on research is a highly profitable investment to society as a whole when cost is balanced against overall benefits...... In the next two decades the resulting return to society in the form of higher standards of living and increased safety to life will be many times the cost of the entire war electronics research.[1]

1. Product Engineering, January 1948.

A. Benefits for the Producers.[1]

1. Atomic Research

Atomic research in its many phases has brought much good and much harm to mankind. Here the harm will be momentarily forgotten in deference to the unlimited amount of good that has already been derived from it.

Radioisotopes, by-products of the atomic pile, have found innumerable uses both in medicine and in industry. As this thesis is restricted to a study of the chemical and process industries those applications of radioisotopes that are not directly related to the topic under discussion will have to be omitted, and this will include most of the applications of radioisotopes to medicine.

Friction studies at the Massachusetts Institute of Technology, have already been aided with radioactive steel. This tracer method has allowed the detection of the transfer of as little as one hundred-billionth of an ounce of material from one surface to another. Better pistons and valves may result. Underground structures of oil fields are being studies with radioisotopes, mixed with mud and forced underground. Strata porosity and oil and water content can thus be measured. Radioisotope tracers study the molecular structure of alloys, and measure the sulphur and phosphorous content of iron and steel. This is expected to result in cheaper and purer products.

1. Ibid; Chemical and Engineering News, January 30, 1950

In producing a new source of power, atomic research is expected to pay off far in excess of the investment. There is a good possibility of producing atomic power competitively with coal or oil. The General Electric Company is building the $20 million Knolls Laboratory under government contract, to investigate the commercial possibilities of atomic power.

In the course of atomic energy research, many new techniques and instruments were discovered which are proving of inestimable benefit to industry. One of these by-products was the development of a "leak detector". Developed in the Manhattan Project by the Westinghouse Electric Corporation and other companies, this was a vital instrument, since the escape of any radio-active gases meant certain death or injury for operating personnel. Now being manufactured by the General Electric Company is a variation of this instrument, which detects leaks in hermetically sealed systems by spraying helium, used as a tracer gas. This instrument tests for leaks in radio-compass equipment for marine and aircraft use, a method far superior to any previous technique. Another variation of this instrument is making for better refrigerators, as used by the Servel and other companies, acting as a production line leak detector which assures perfect inspection of gaseous systems in air conditioning and refrigeration equipment, at an extremely rapid rate. The possibilities for similar uses in the chemical industries are very great, especially in such fields where toxic gases are a part of a reaction and their flow has to be strictly controlled, this method also simplifying the detection of leaks in any toxic gas system. In all these uses the tracer gas results in greater production economy, and product and production safety, two very important considerations at a time when costs are on the upgrade and the use of more and more dangerous gases and liquids is expected to increase.

Another indirect benefit of atomic research has been the development of pumps which can create vacuums hitherto unknown to man. In many modern production techniques, such as the coating of plastics and other materials with metals, extremely high vacuums are required. To produce more efficient vacuum tubes and coaxial cables for modern television and high frequency electronics, better vacuums are also necessary. This high degree of "emptyness" is now assured with oil diffusion pumps developed during atomic research.

The tremendous research done on the atomic energy project in the field of fluorine chemistry has already borne fruit. The taming of this unruly gas promises a far reaching expansion of industry which will create countless new products ranging from improved paints, plastics, insecticides and textiles, to better electrical apparatus, and better automobiles made possible by lubricating oil so stable that gears and engines can be radically redesigned.

A new class of compounds discovered, known as the fluorocarbons, are important because, unlike the hydrocarbons, they will not burn and will not react with any of the common chemicals. As lubricants, they promise to be far superior to conventional oils and greases for heavy duty bearings, where high pressures and temperatures are encountered.

2. Electronics Research

It has often been said that World War II was an electronic war. Automatic gun direction, radar, navigation instruments, "proximity" bomb bursts - all these required improvement and development of electronic components to a hitherto undreamed-of extent.

One of the most spectacular developments to emerge from military electronic research was the radio proximity fuze, officially known as the VT (variable time) fuze. Instead of being forced to make a direct hit on an enemy target, the VT fuze made it possible for the bomb to explode within a certain radius of the target. Although this discovery does not seem to have too much bearing on the chemical and process industries, it brings the topic of the thesis back to conservation, concerning the wood and pulp industry.

Fighting forest fires has always been one of the greatest dangers in the attempts of the American people to conserve their natural resources. The above mentioned proximity fuze has thus been put to use in this continued fight against the elements. Under a cooperative arrangement between the United States Forest Service, the Army Air Forces, and the Bureau of Standards, experimental forest fires were recently extinguished in the Lolo National Forest, near Missoula, Montana. American Air Force planes dropped 165 - gallon water - tank bombs, which, under control of the VT fuze, exploded over the fire at the height which had previously been calculated to have the greatest effect. This method has since been proven in a number of actual forest fires during the past year and has thereby shown that in another field, war research has brought many benefits to peace time production.

A good part of the "higher standards of living" and "increased safety to life" referred to in the statement of Dr. Terman, as quoted five pages back, has come as a result of radar research. Better, more efficient fluorescent lighting is a concrete result of research on radar screens and has found its way into every single industry in the United States for that reason. In the category of safety, radar has made an outstanding showing. One of the first peacetime applications of radar has been for marine navigation. For the first time, a vessel need not lay over in port because of possible accidents in fog or adverse weather. Operators of a radar-equipped Standard Oil towboat hauling petroleum products on the Ohio River, estimate savings to be as much as $100 an hour, in the form of additional wages and the like.

3. New Techniques Developed

One of the most important techniques developed and accelerated by war needs was the use of large-volume oxygen. Formerly used in small, expensive quantities - mainly in medicine - oxygen is now being manufactured cheaply and in large quantities, as a result of war research. First, a portable oxygen-producing unit, to meet the needs of the armed services, was developed by the M. W. Kellogg Company, under contract from the Office of Scientific Research and Development. At present, large-scale production of oxygen is making synthetic gasoline from coal possible as described in Chapter VIII (2). This is a variation of a process the Germans used during the war, and is much more efficient. This method of manufacturing oxygen has also been utilized by the steel industry in producing a more efficient production of steel and at a lower cost from the openhearth furnace.

Non-metallic materials, such as plastics, also saw tremendous advances. The revolutionary class of silicone materials are already being applied in at least half a dozen forms. Extremely stable to heat, electrical forces and many chemicals, this material is finding use as elastic and rigid insulation, as grease and oil in lubrication, and as a resin to bind high strength laminates. Polyethyline, another new material, is now finding extensive use as food packaging and electrical insulation. Still another is Teflon, a waxy material which has phenomenal resistance to all type of corrosive agents.

New types of rubber were developed. Scientists during the war changed rubber from an electrical insulator to a conductor of electricity. Sheets of this rubber became warm when an electrical current was passed through them. Developed by the United States Rubber Company, during the war, they were made into heating elements to prevent formation of ice on propellers and wing guns of Army airplanes. Now they are being installed in homes to provide heat, and at the present time a four and a half room bungalow in Knoxville, Tennessee, is being heated by this method for about $50 a year.

Cellular rubber was developed during the war to protect occupants of armored tanks from head injuries while travelling over rough terrain. The remarkable cushioning properties of this rubber are now being utilized in a packaging material to protect television tubes and other delicate equipment, and has opened up a new field of utilization for the products of this country's rubber industry.

Many new techniques were developed in government laboratories themselves. The Naval Research Laboratory, for instance, was responsible for the following developments:
a) A non-flammable hydraulic fluid, composed of polymer-thickened solutions of ethylene glycol, which is now being

tested for use in commercial airliners; b) synthetic lubricants - these synthetic greases and oils are proven superior for specialized uses to conventional petroleum products; c) a rain repellent developed for airplane windshields is now being made commercially by the Norwich Pharmaceutical Company.

These are only a few of the results of war research and their application to the production processes of a peacetime economy, but they should suffice to show that research in this line is well worthwhile. Many wartime discoveries are still protected by government secrecy and many more have been withheld from the market as they might give too much of a competitive edge to that group which would be utilizing the knowledge thus obtained. However, the work that has been done so far has given management many satisfactory solutions to its problems in the way of production processes, lower prices, and marketable products, and much more research is being carried out at the present time about which nothing can as yet be written.

B. Benefits to the Consumers.[1]

1. Medical Research

Benefits of war research, affecting every man, woman and child in America, abound in the field of medicine. These developments, while perhaps not as glamorous as atomic

1. Product Engineering, January 1948.

discoveries, are nonetheless real. Tremendous advances in medical research were made at laboratories all over the country, under the general direction of the Wartime Committee for Medical Research of the Office of Scientific Research and Development, headed by Dr. Alfred N. Richards, President of the National Academy of Sciences and Chief of the discoveries, are nonetheless real. Tremendous advances in medical research were made at laboratories all over the country, under the general direction of the Wartime Committee for Medical Research of the Office of Scientific Research and Development, headed by Dr. Alfred N. Richards, President of the National Academy of Sciences and Chief of the Medical School of the University of Pennsylvania.

One of the most spectacular medical advances of the war was the production of penicillin. What was accomplished in a few short years, would have ordinarily required a decade or more. Penicillin was a laboratory curiosity before the war; its testing and clinical application, as well as its efficient production to bring the price down to the level of the average man, is a tribute to American scientific genius. In this, the executive, research, engineering, and production staffs of about twenty manufacturers, the Northern Regional Research Laboratories of the Department of Agriculture, the War Production Board, the Office of Scientific Research and Development, the Food and Drug Administration, the Office of Production Research and Development, the National Research Council, the National Institute of Health, and other official and semi-official agencies had cooperated.

Another antibiotic to come out of the war is streptomycin, which was discovered by Dr. Selman A. Waksman of Rutgers University in 1944. As soon as it was shown by researchers at Merck & Company, Rahway, N. J., that streptomycin could combat such diseases as tularemia, influenzal meningitis, and certain urinary tract infections, under strength of recommendations of Army and Navy doctors, the War Price Board granted priorities for plant construction. Streptomycin has recently shown excellent results in the treatment of tubercular sinus trouble and tubercular kidney disease.

An ironic result of war research now promises to benefit the fight against cancer. It was discovered that a mustard gas chemical, developed in research to kill or incapacitate human beings, arrested certain types of cancer in laboratory animals. This chemical, known as "HN2" was discovered simultaneously and independantly at the Yale University and Chicago University Medical Schools, under a program of the Chemical Warfare Services. More than a thousand people have already been treated with this compound and results are being evaluated at the Memorial Hospital in New York. While physicians are reluctant to make expansive claims for HN2, it has already proved useful as a palliative treatment for leukemia and Hodgkins' disease, cancer of the lymph nodes. Although doctors insist that there is no known cure for cancer, HN2 has proven useful in relieving symptons such as pain, poor appetite, and damage to the nervous system.

A natural result of a global war is the fight against global disease. Malaria, which has always been something of a problem in the southern part of the United

States, became an active menace to our troops fighting in far flung Pacific and African outposts. This problem was attacked simultaneously in laboratories all over the United States and in England. Three new anti-malarial chemicals resulted, which are now in peace-time use. These are: a) Chloroquine, which is a suppressive for one type of malaria, but is better than atabrine; b) pentaquine, which actually cures malaria, although it is sometimes used with quinine; c) paludrine, an English discovery which acts like chloroquine.

New insecticides and rodenticides were discovered and promoted by war research. The spectacular chemical DDT, although it was discovered by the Germans in the last century, was developed for actual use under research contracts of the Office of Scientific Research and Development, and the Department of Agriculture. The peace time use of DDT "can scarcely be overestimated," according to Dr. Richards. "Its usefulness in aborting the typhus epidemic in Naples was a dramatic demonstration of its value. Its usefulness against all sorts of insects is being demonstrated daily."

Now, it may be possible to wage an effective war against rodents with the use of ANTU and similar chemicals. Another excellent rodenticide, known as "1080", was discovered and is now being made commercially. Plant growth regulators such as British Anti-Lewisite (BAL), are putting plant growth on a more scientific basis.

2. Aids to Personal Comfort.

Promising more comfort to the individual in the winter is a Navy-sponsored program for bioligical research within the Arctic Circle. Conducted by civilian scientists of Swarthmore College and Cornell University, the group will study the expenditure and economy of animal heat.

Of more immediate use are the various chemical treatments for cloth that were developed during the war, primarily for military use. Heating and humidity cause mildew, fungus, and shrinkage. On a less severe scale, but perhaps just as prevalent, is mildew and fungus-growth in the coastal areas of the United States. A war-developed chemical, copper-8-quinolinolate, which prevented clothing, tent fabrics and other cotton and leather articles of personal equipment from deteriorating, is now being produced commercially by the Monsanto Chemical Company. It has been stated that if "copper-8" were incorporated into tanning agents for leather, transmitting athlete's foot in shoe stores would be impossible; wearers of such shoes would have less chance of picking up the fungus.

A shrink-preventative process was developed for the armed services by the Harris Research Laboratories, Washington, D. C. Constant replacement of woolen socks had become a serious problem in the Army and Navy. Approximately 100,000,000 pairs of socks were treated with this process, with the result that the average life of the sock was doubled.

This treatment makes woolen garments resistant to shrinkage during laundering.

Winter clothing will be lighter, warmer, and more comfortable, as a result of still another war development. First discovered at the University of Michigan was the fact that the silicagel, which ordinarily is used to absorb water, when treated with a monomolecular layer of a special chemical, acts as a remarkable insulant. A large rubber company is now experimenting with clothing made from rubber latex with the silica-gel bonded into it. This material has the property of keeping the water out, but allowing body moisture to evaporate through it. Jackets made from a single layer of this material were recently distributed to duck hunters all over the country for experimental wear; reports were unanimously enthusiastic.

The two portions of this chapter have mentioned in some detail the numerous advances made during the war which have benefited industry and the consumer. More specifically, benefits to management have to be found in the effects or applications of these advances.

Before the war the field of biologicals and pharmaceuticals had fallen into somewhat of a slump in as far as the production of medicines was concerned, partly through the availability of German materials and partly through purely intra-industry reasons. The war brought about numerous new discoveries in this field which aroused the industry to such an extent that it is at present one of the most active in the country in as far as products turned out is concerned. The inventions of radar and the uses of radioisotopes have made a considerable dent in the list of accidents both in industry and to the population as a whole. The use of radioisotopes to detect leaks has solved one of the most pressing headaches of the management in the chemical and process industries which has always been plagued with comparatively poor safety records.

Although the use of atomic energy as a major source of power seems to be somewhat premature, the work of the General Electric Company in their newly established Long Island plant seems to indicate that there will be a considerable saving in power costs as soon as atomic energy can be harnessed successfully. Of more immediate interest is the fact that the fluorescent light, also a major war development, has already made a considerable reduction in the power consumed in offices and factories while supplying the same amount of illumination as formerly. These are only a few of the examples mentioned in the text of the chapter and there direct relationship to management problems at the present and in the future. Such work as the research that resulted in synthetic toluene and synthetic rubber speaks for itself.

Although the direct benefits to the consumer, as coming directly from war research, are not as numerous as those to industry as a whole, the words of Dr. Terman quoted previously are very true. Society as a whole has benefited greatly from the tremendous research programs carried out throughout the years of the war, and the society of the future will benefit the same way from expenditures the government is incurring at the present time in both atomic research and the other branches of research that it believes will have a direct bearing on any future war. For this reason the criticism of federal expenditures in this field should be restricted to those who know more about the actual financial requirements for such a program, such as the managerial directors of industrial research who in the future will be putting the government's research results to use in their own specific fields.

CHAPTER XI

EVALUATION OF INDUSTRIAL RESEARCH

At a time like the present when research is playing such a major role in the chemical and process industries, some of which are spending as much as five percent of their annual net sales on this one field, it is of the greatest importance to management to be able to determine by some method the dollars and cents value of their investment. There is an obligation on the part of every research director to prove in clean, crisp terms that the results obtained from large sums spent on research and development comprise an adequate dollar return.

To satisfy this desire on the part of management the Western Cartridge Company division of Olin Industries, Incorporated, is at the present time using an "Index of Return on Research" as evolved by the Research and Development Division of the latter organization. Fred Olsen, the Director of this Division, has given a number of addresses before chemical and engineering groups throughout this country on this scheme, and the remainder of this chapter is an attempt to present the substance of these talks from the available transcripts of his speeches.

A. Index of Return on Research

The success of an industry today is certainly dependent on the quality of its management. The principal measures of quality in management which indicate success or failure largely depend upon:

1. The clear recognition and statement of the main purposes of the corporation.

2. The ability to guide and control the operations so that these purposes are achieved.

The presidents of several nationally known corporations were asked what they considered to be the main purposes of their companies. Amazingly enough few top executives had committed to writing a statement of their purposes or of the policies which they had adopted for the successful achievement of those purposes.

Most of these executives agreed that the main purpose was to earn a good reward for the owners of the company - the stockholders. They also agreed that their objective was to increase the earnings.

When asked more specifically, "Is one of your goals to double the profits of the corporation within say five years?", they agreed that such a thing would be desirable. It is obvious, however, that they have laid down no policy covering the desired rate of growth of the corporation. No point is more vital to a corporation than establishing this policy for the rate of growth of the corporation.

Even a more casual consideration of the projected growth curve reveals that this cannot be based merely upon a desire for increased profits but must involve a whole train of other items of policy. It might be thought that the simplest way to double profits would be to double the sales volume, either by increasing the size of the factory or by building a new factory. Such a decision can only be based upon accurate knowledge of the market potentials, upon the ability of the corporation to acquire and train new personnel, and upon the availability of extra capital with which to finance the expanded activities. Furthermore, market studies might show that sales could be increased if costs could be lowered, and hence the task is thrown into the lap of research to discover new processes which lower the costs.

However, in most businesses, the doubling or multiplication of sales volume is frequently just not possible, because the market is too nearly saturated with the article being produced, and part of the business is too strongly held by competitors.

New dollars can usually be made only by new products. Increasing earnings by developing and selling new products is perhaps the most successful technique discovered by this country's most progressive corporations.

This brings to mind a company whose sales volume has increased nearly ten fold in the last twenty years. Two thirds of their current products are new products, - that is, they were not in existence twenty years ago, and these were all created through research.

To accomplish this management turns to research for guidance. Management expects that research will provide the charts for future courses of action. More specifically, management views research as the insurance for maintenance of its future profits. Research must bring into existence new products which will utilize the talents and resources of the corporation and will integrate and strengthen the total activities of the company.

However, its existing products must not be neglected, and research must improve the quality of the current products so that a strong competitive position in the sale of these products can be assured. Likewise, research must improve the processes by which these products are produced.

Costs must be reduced so that profits can be secure.

In a corporation where research and top management are well coordinated, research will present the chart for future expansion of the corporation. Research will estimate the approximate capital required for this expansion and the time schedule on which the capital should be available. Management's function is to set the policy as to how much of this proposed expansion will be adopted and to provide for the financing.

Assuming competent operation of current manufacture and sales, it will not be possible to double sales volume other than by new products made in new factory facilities. Taking as an example a corporation where annual sales of $100 million, doubling the sales will roughly need $100 to 125 millions new investment in plant, following $10 to 15 million spent on successful research. In short, management views research as one of the main factors in protecting the future success of the corporation.

Unless this broad viewpoint is maintained, research may wonder into fields not properly correlated with the logical expansion of the corporate interests. On the other hand, research may become so narrow as to be concerned mainly with the detailed and esoteric practices of the laboratory. It is top management's job to set the policy into which fields the company will expand with new products.

It is a fair statement to say that strong leaders of industrial research are primarily concerned with economics and only secondarily with technology, referring to economics and not economies. It must be said, however, that in saying this the allusion is not to the application of finicky bookkeeping practises to the operation of a research department. Nor is the importance of high scientific achievement minimized. Even the highest scientific achievement is only of use to society when it is directed towards sound commercial and social ends by wise management. It cannot be denied, that management is increasing its demand for proof that the research dollar is earning a good return. Management is growing more skeptical every day about research programs based on blue sky profits.

Indeed the day is rapidly approaching when research laboratories will have a sort of investment policy similar to that of a prudent man who has in his portfolio a balanced assortment of bonds, preferred stock, and common stock. By analogy, the research department should expend its efforts partly on short range jobs which are certain, and which will bring in a needed but small return. Those are the bonds. It will also expend a smaller proportion of its effort on longer range items in which the element of speculation is more pronounced. Those are the common stocks. In each case, it will be a matter of policy to calculate the probable reward and to balance this reward against the risk. The more original and the more daring a new concept, the greater is the risk that it cannot be brought to fruition. However, even a conservative management is glad when the research department comes up with good, brilliant ideas which challenge management to give a strong vote of confidence.

Management wants evidence of courage, enterprise, and enthusiasm in its research staff and frequently it will approve acceptance of quite severe risks when the anticipated rewards are correspondingly great. But it will only support the expenditure of large sums on long range research when the research department has a background of proven accomplishment. This background of accomplishment can be accurately evaluated only where acceptable yardsticks exist with which to measure the value of research.

In discussing the evaluation of research, it would be well to indicate what kind of values are to be considered.

It is taken for granted that important aesthetic values exist for those who find deep satisfaction in the performance of creative work; that vital political values exist for the nation which possesses such fruits of research as the atom bomb; that great economic values exist for this country as a result of such researches as the cracking of oil which has conserved the former's essential mineral wealth. Likewise, it is taken for granted that great cultural values have come from the development of the radio, television, etc.

Management is becoming acutely aware of its responsibility for participating in the cultural, social, and political affairs of the town, the state, and the nation. The Public Relations departments of large corporations are becoming increasingly alert to the public interest in the research efforts of their company. Particularly is this true where new discoveries have brought into existence new industries, new employment, and new benefits to the public.

These are the broad gage values springing from research, and it is believed that these values really motivate most of those pursuing research work.

However a very narrow measure of values is being referred to here, the dollars and cents profits which comprise one yardstick by which to measure the value of research. This money value is chosen because, as the corporation tax rate has decreased from wartime high levels, top management has become quite critical about the returns to be obtained from the research dollar.

The glamour of research is good for the courtship period, but to keep management wedded to the idea of continued research requires continued and substantial profits.

Most Research Divisions, in submitting their annual or periodic reports, call attention to their outstanding successes of the past year, and may even point out how much increased sales has resulted from the new product or how much valuable raw material has been saved as a result of an improved yield in a new process. Here a more precise auditing of research is discussed.

It is usually fairly easy to evaluate a new process where increased yields can be shown, or where reductions of labor or more effective utilization of by-products have been established. Nevertheless, it is important to apply formal methods to secure financial data that will have the same kind of acceptability with a Board of Directors that data on profit and loss from manufacture and sales operations receive.

The Research Division's position in the corporate structure will be much more clean-cut when its output can be appraised with the same objectivity with which management measures sales and manufacture.

In Olin Industries when a research project is completed, a formal report called a Technical Proposal is submitted to the Works Manager, by the Research and Development

Division. This Technical Proposal outlines precisely how the proposed process will work in his factory. The specifications of all materials entering into the process, are given. Also, the controls which are necessary to establish the quality of the final product, and sometimes of the significant intermediate products, are included. Supporting data are given for each step in the process, based upon laboratory or preferable pilot plant runs. The type of apparatus used to secure these data is described so that factory engineers may design appropriate full scale equipment, based upon the engineering data provided on the small scale runs. A Technical Proposal also contains a statement from the Sales Department to the effect that the product made by this process is acceptable to them in comparison with the product made by the prior process. The Patent Department "clears" the process as not infringing current patents.

An estimate is furnished by the Financial Section of the Research Division to show the additional earnings which this process should produce over the current process. If the saving is large the Factory Manager will realize the importance of putting the process into immediate service. Management will hold him responsible for the loss incurred each day the proposed process is kept out of operation.

Management has prescribed the policy that this Technical Proposal must either be accepted for plant trial by the Factory Manager or be rejected for causes stated. The Technical Proposal just cannot rest idly on someone's desk. If it is rejected the Research Division then has an opportunity to correct errors which have been discovered by the scrutiny of the factory staff. Experience has shown that these errors can be greatly reduced by involving appropriate members of the factory staff in the development project even from its earliest stages.

When the Technical Proposal is accepted for factory trial, the Cost Accounting Department lays down the base line for the costs, as they occur in the existing process, as to raw materials, direct and indirect labor, yield of finished product, amount of scrap, steam, water, power, and all pertinent overhead items. The same accountants examine the operations after the new process has been under trial usually for three months. All changes in costs are attributed to the new process, and the savings are recorded quarterly for one year. These process savings constitute one item of what is known as an Index of Return.

It is admitted that this recording for one year is entirely arbitrary, since the improved process may continue in operation and earn additional savings for many years. However, the main point is to secure agreement with top management for some acceptable method of evaluation, and then use the information so collected for measuring the progress from year to year.

A real difficulty is encountered when an attempt is made to place a value on an improvement in an existing product. If a product is not improved, it may lose the acceptance of the customer, or it may require additional expense in advertising and sales promotion to maintain the previous sales volume against improved competitive products. In the event that increased sales of an improved product are secured, it is almost impossible to determine to what extent this increase is due to the improvement made by research and what is due to the extra efforts of the Sales Division.

After much study, Olin Industries adopted a plan of recording 3% of the net sales of an improved product as a measure of its value. Again this is only recorded for one year. Admittedly this percentage is arbitrary and may not be appropriate with other companies for different types of product. Likewise, the interval of one year is arbitrary. The basis upon which the number was selected in Olin Industries was that many progressive companies have adopted a policy of allotting an amount equal to 3% of their net sales to the research budget. The argument, therefore, is that if 3% of total net sales should be spent on research to maintain the quality of the company's products against competition, then 3% ought to be regarded as a conservative measure of such products as are improved.

Again the endorsement of the Sales Department for the improved product is a necessary feature of the Technical Proposal which transmits the project to the Works Manager.

When a new product is developed, the same 3% of net sales is recorded, but this time it is done for a period of three years because of the admitted added difficulty of developing a new product to its maximum sales.

These three items - 1) savings on improved processes for one year, 2) 3% of net sales of improved products for one year, and 3) 3% of net sales of new products for three years - are added and called the "Index of Return". This Index is compiled each quarter and recorded graphically to show comparative progress. The same chart records the research expense during that quarter. Obviously, the expense in that quarter is not related to the earnings in that quarter since there is almost always a year's, and probably two year's lag between expenditure of research funds and the consummation of the project in the form of actual production. (see Chart 1)

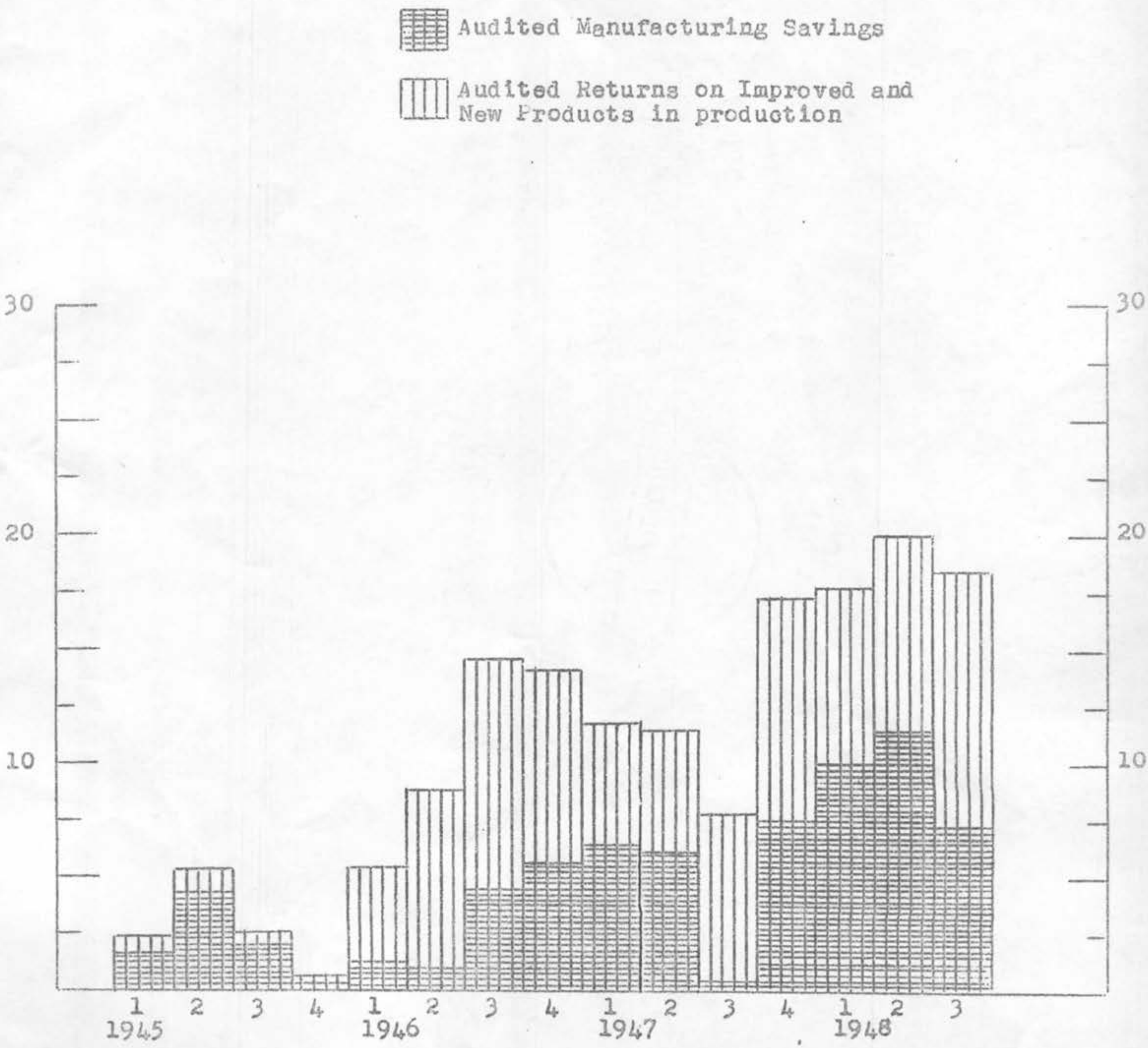
In addition to informing the Board of Directors what progress is being made from quarter to quarter, the same chart carries two other items. One is the estimated Index of Return for completed projects, the Technical Proposals of which have been accepted by the Works Manager, some of which are in actual operation but for which audited returns are not yet available. The other is an estimated Index of Return on projects which have been completed, but the Technical Proposals for which have not yet been accepted

1

Chart 1

INDEX OF RETURN

On Research Projects Adopted by the
Western Cartridge Company
Factory at East Alton,
A Division of Olin Industries, Inc.



by the Works Manager. Both of these items constiture a backlog of developments which should shortly come into operation, and the extent of this backlog informs the Directors what can be anticipated in the near future. (see Chart 2)

Experience has shown that the estimation of the probable Index of Return can be done with sufficient accuracy to serve as a reliable guide to future operations. Obviously, the estimates are made by the same technique of accounting that are applied to the proven operations. (see Chart 3)

One important application of this device is to permit the management of the Research Division to determine what projects should be worked on. For example, if manpower exists in the Division capable of carrying out, say, 50 projects, and 70 have been offered for consideration on the budget for the following year, this Index of Return device is used to select the best project. Selection is then made of new items which show the greatest estimated Index of Return.

Use is made of the familiar formula which has been mentioned by R. E. Wilson, Chairman of the Board of Standard Oil of Indiana, and by others, which comprises the ratio:- estimated return multiplied by probability of success divided by estimated research expenditure. Admittedly, the significance of this ratio depends on the judgment

Chart 2

2

INDEX OF RETURN
On Research Projects Adopted by the
Factory at East Alton

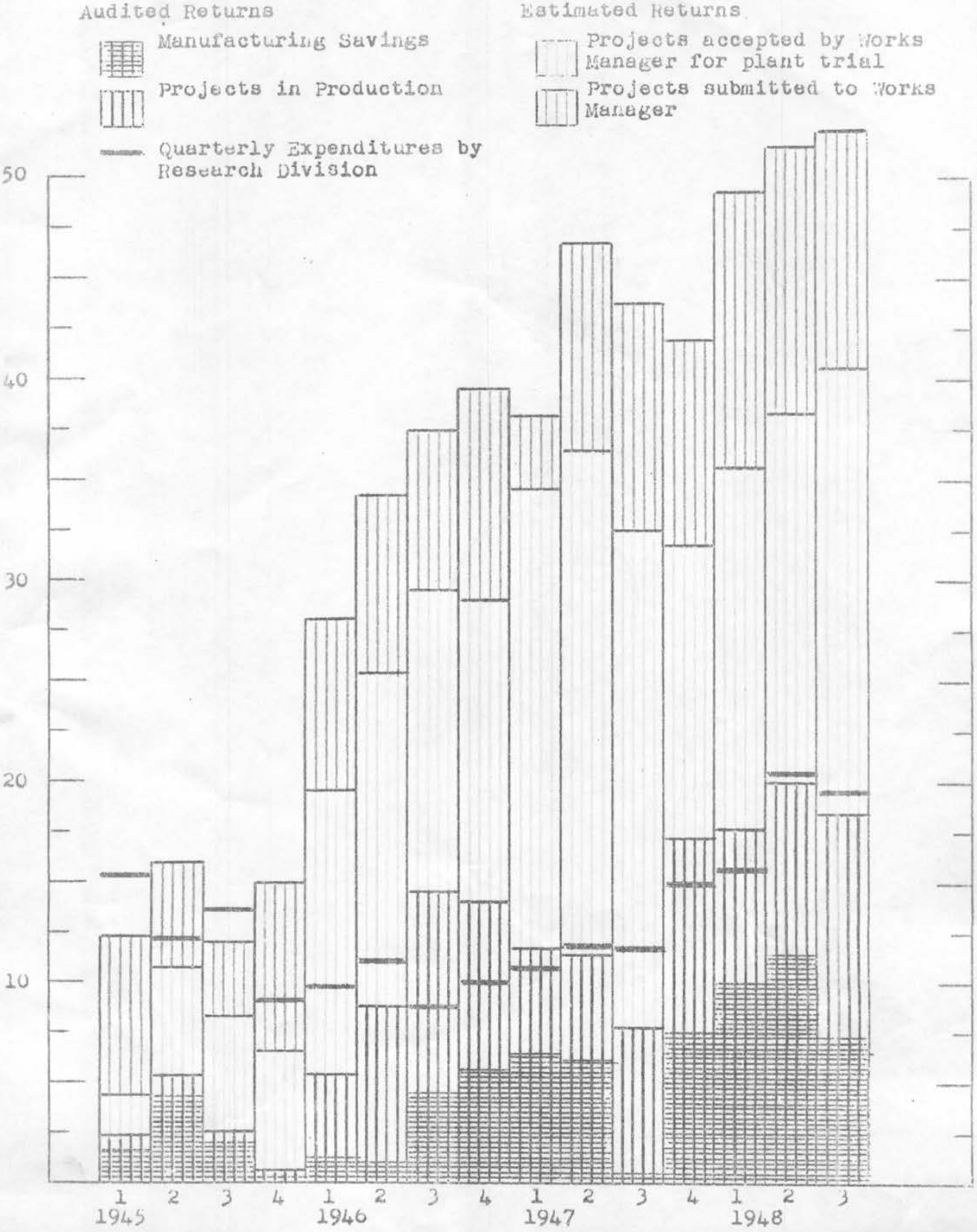
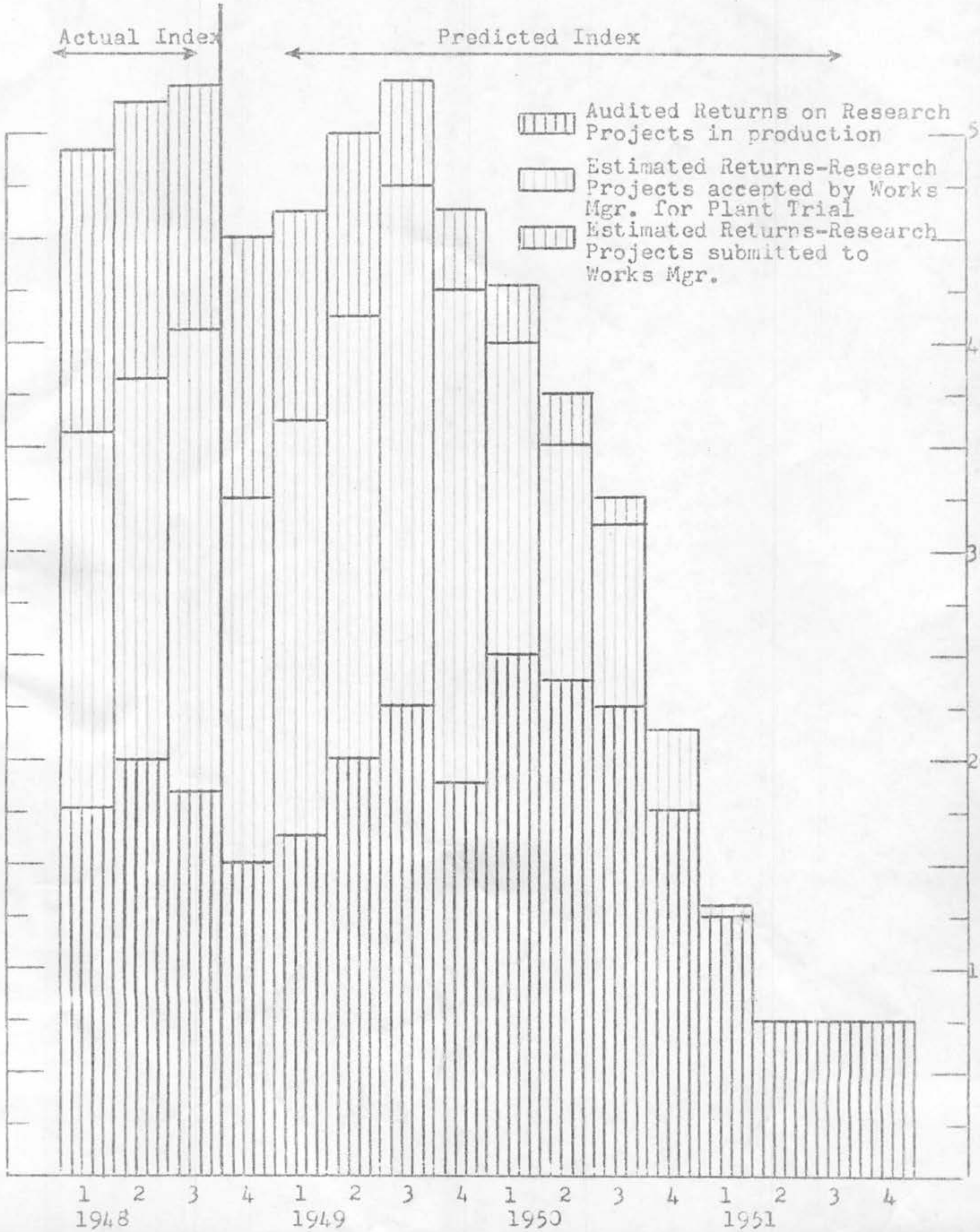


Chart 3

INDEX OF RETURN
On Projects Conducted by the Research & Development Division, Western Cartridge Company, a Division of Olin Industries, Inc.

3



displayed in estimating the probability of success, as well as the estimates of return and the amount of expenditure necessary to complete the project. In Olin Industries' operations, this ratio should be not less than 3-1, or they would be exceedingly dubious about the desirability of starting the project. Some people who use this type of formula set higher ratios, but it should be remembered that Olin's returns are recorded only for one year for process and improved products, and for three years for new products.

Although this device of the Index of Return has been used for several years to measure the effectiveness of Olin's research effort, it ought to be emphasized that it does something else. It measures the ability of the Sales Department to sell the improved or new products. Still more broadly, the Index of Return is one measure of the success of the total corporation in replacing current products and processes with better ones.

Perhaps the most significant feature of this Index of Return is the challenge it makes to the Research Director to enlist fully the cooperative efforts of factory and sales, and to demonstrate to top management the intimate harmony with which this team of Factory, Sales and Research does function.

Thus management's view of industrial research need no longer be a matter of unfounded conjecture. Rather, management's view of industrial research can be objective -

as impersonal and unprejudiced as the other scientific evaluations which come out of the research laboratory. Management can ask research to submit its results to the same kind of audit as is used to measure the productivity of the factory or the Sales Department.

Finally, the Index of Return serves as a device by which the technical activities and potentials of research can be meshed continuously with management thinking.

Management is thus given a new tool by which to measure the past performance of research. It is also given binoculars through which to view the future.

CHAPTER XII

CONCLUSIONS

The conclusions to be drawn from this study of research have been largely made within the chapters themselves. Every chapter within its pages holds the solution to one phase of managerial work. No longer can there be any denial of the fundamental nature and absolute necessity of research in the chemical and procèss industries and the final proof of this is in the fact that at the present time that industry is still at the top in comparison to the rest of industry when comparing its sales volume and profits with those of the pre-war years.

Of the $1,200 million spent annually on research, industry consumes more than $450 million, and the government the rest. To demonstrate the importance of research to the chemical and process industries it has been determined that approximately one-fourth of the latter figure spent by industry as a whole is spent by the oil companies on the research that has resulted in the numerous advances and products discussed in this work. Due to this fact the oil industry has kept detailed records of its research expenditures and returns, and has found out that research really pays dividends. The Standard Oil Development Company, one of the foremost oil research organizations in this country, has shown that returns over a ten year period on every dollar invested in research were $15.41, accounted for from three major sources. The savings on royalties that would otherwise have had to be paid out to competing companies amounted to $3.72. The savings due to improvements in existing processes and products that had to come about in order to keep Standard Oil of New Jersey in the competitive picture totalled $9.62. The last part of the return on the research dollar was made up by $2.07 of added profits due to new products.[1] Nothing speaks better in this analysis than these actual dollars and cénts figures, and those mentioned above are the assurance that the oil industry will continue expanding its research facilities.

Although there are many fields of research that have been somewhat neglected over the years, it has been the attempt of this work to show them all in the light of their actual importance. One of these fields, so badly neglected till recently, is that discussed in Chapter VI under the title of "Utilization". Only in the past few years has it been made clear to management of industry, and especially to that of the chemical and process industries, that raw materials do not stem from an unlimited source and that waste and effluent in rivers is not only a great expense to communities but also harmful to animal and vegetable life. This realization has been the necessary push to make management take advantage of the services of research in turning

1. Pamphlet of Universal Oil Products Company

these factors to profit by substitution and utilization. In the years to come these phases of research will be given greater and greater importance due to the fundamental nature of their purposes.

A similar lack of the realization of impending doom exists in the textile industry, and only under the extreme pressure of synthetic fibers is the textile industry realizing the importance of research in the field of improving the properties of its products. Some of these results have been discussed in Chapter VIII but the actual research resources at present being utilized for this purpose are nowhere near enough to maintain the position of the natural fibers in the face of such phenomenol fibers as nylon, orlon and saran, which in the foreseeable future will have sufficient price reductions made in their methods of manufacturing to be able to compete in the same market with the natural fibers. In order to avoid this depletion in the consumption of natural fibers, management has had to turn to research to improve the properties and applications of the fibers in the form of impregnating chemicals.

The pressure of war and the shortage of certain strategic materials brought management face to face with the problem of finding substitute products. As was explained in detail under Chapter IX, not only did the products and processes thus discovered by research under the pressure of war fill the need of the time, but emerged from that situation to take their rightful place in the production line of the post war competitive market. These products have given management a wider field for their ever hungry sales department and have given them a large source of increased revenue.

The field of plastics is a unique one, as was demonstrated in Chapter V, in the infinite variety of its forms and applications. The plastics have not only increased in production more than ten fold in the last ten years, but they are replacing more and more other materials both in the field of household utensils and structural members. As a class by themselves they are probably the most lucrative of all the products that have come from the research laboratory.

A fact not generally appreciated by the public is that the greater part of the chemical and process industries is almost entirely devoted to the production of chemicals and raw materials which are used as intermediates for other manufacturers. As a whole the industry makes few finished products, and hence if it increases its total number of employees over the years, as it has done with the new products continuously being placed on the market, additional thousands are added to those industries which use and sell the products of the chemical and process industries. This has been one of the major contributions of management to the labor picture in the United States, a contribution arising directly out of the utilization of the products of the research laboratories.

Research under government sponsorship and at government cost has been developed to a greater extent in the last ten years than ever before. This was largely brought about by the recent war, but after the end of World War II the research projects still continued to multiply. Outside of atomic energy the greater part of government expenditure is in those fields in which management has no immediate interests, either due to the fact that the profits to be obtained from the study being conducted do not warrant the expenditure, or because in the foreseeable future there seemed to be no need for the results of this research. The synthetic rubber industry, strictly a war baby, falls into the first of the above categories, and if it were not for the price and production quantity support of the product by the government it would be very difficult for the producers to meet costs under present competitive conditions with natural rubber. This situation will be demonstrated even more realistically in the first week of July when the synthetic rubber industry will be turned over completely to private enterprise by the termination of the Rubber Act of 1948.

The study of synthetic fuels being conducted by the United States Bureau of Mines falls into the second category as mentioned previously largely because the oil companies at present see little cause for fear that their oil resources are dwindling and are therefore unwilling to spend the necessary sums of money that are needed to conduct the research. The United States government however thinks it its duty to investigate this field in order to be able to aid management, when the time comes, to be able to continue to place as much liquid fuel on the market as the country needs, especially in case of another war.

It has been largely through the efforts of research, in one of its many phases as discussed in this work, that has brought this country to the position of leadership it now holds and the esteem that it is looked upon by the rest of the world. That which has given rise to this is the stimulation of scientific research to gain increased knowledge of the materials and forces of nature, so that this information can be used through ingenuity and skill to create new and improved products for industry, to find industrial applications for farm products, and to handle more efficiently this country's dwindling natural resources. Increased technological advances through research will continue to expand markets, decrease costs, introduce new products, and create new industries.

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