THE SEARCH FOR NEW MATERIALS BY INDUSTRY

215

13 September 1951

CONTENTS

Page

INTRODUCTION—Brigadier General J. L. Holman, USA, Deputy Commandant for Education, ICAF 1

SPEAKER—Dr. Winfield W. Heckert, Technical Director, Rayon Department, E. I. du Pont de Nemours and Company..... 1

GENERAL DISCUSSION 13

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THE SEARCH FOR NEW MATERIALS BY INDUSTRY

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GENERAL HOLMAN: Gentlemen: We live in an exciting age—and no small amount of all the excitement is directly attributable to the research engineer. In his unceasing quest for new materials, the research chemist or physicist has the capability of making great changes in our homes, our clothing, the state of our health, our movements and communications, our bank accounts, and even our dispositions.

Most of these changes bring with them increased comfort, security, and other blessings, but they have also increased and will continue to increase the intensity and risks of military operations. The penalty for having second-best equipment in any category at any time could have a pretty high price tag.

We must therefore keep right up to the minute with respect to new materials and their influence on weapons, both current and future. To do this, we must consult industry as a continuing procedure.

Dr. Winfield W. Heckert of du Pont is our guest speaker this morning. He will take us behind the barricades of industrial research to increase our knowledge of how industry conducts its search for new materials in the industrial complex which is a large segment of America.

Dr. Heckert brings to us the knowledge and experience of many years in the research field with the du Pont Company and is presently Technical Director of its Rayon Department.

Dr. Heckert, it is a pleasure to have you with us and to welcome you to this platform.

DR. HECKERT: General Holman, gentlemen: In order to do justice to the subject which you have assigned to me, one would have to survey the industrial research effort of the entire Nation, an assignment far too ambitious for a 30-minute talk. This I shall not attempt to do, for aside from the difficulty of treating so complex a subject in so short a time, I am really quite unqualified to speak for the chemical industry as a whole. My experience has been limited solely to du Pont, and for that matter largely to one segment of the du Pont Comapny's business, for during the past 20 years I have been solely concerned with man-made fibers.

During this period have emerged the tire-cord rayons, such as our "Cordura" high-tenacity rayon; the first true synthetics—nylon yarn and staple; the acrylic fibers such as our "Orlon" brand yarn and staple; and polyester fibers such as our new "Dacron" brand yarn and staple. These and other synthetic fiber developments have kept the textile industry in such a state of ferment during recent years that it can be

truthfully said that the synthetic fiber industry has been doing its share of the "searching for new materials."

If you are willing to examine industry's search for new materials through eyes which are admittedly somewhat blurred by overexposure to new fiber products, then I shall try, within the limits of my ability, to give you some conception of the different approaches used by industry in its search for new materials. Some of the new fiber products are (1) tropical worsted trousers which will retain their creases even when washed, (2) winter suitings which have warmth and durability exceeding those of wool, (3) fabrics which will not burn even when held in a gas flame, (4) shirtings which do not wrinkle and require no ironing, (5) an occasional permanently pleated nightgown, and (6) a pair of semi-controlling panties.

Let me say at the outset that modern industry is a dynamic, evolving phenomenon of our times which neither existed nor was visualized by the savants of 50 years ago. The very words they used to describe business institutions and their operation must take on new meanings if used today, else they convey wrong impressions. For example, not so many years ago "to compete" meant to contend in the market place with other producers of the same product. But today the customer chooses as often between different products as between different producers and sometimes even chooses between whole industries.

It is not so much the competition between producers of the same product which is setting the pace of economic progress; rather it is the competition between producers of widely different products. Thus, nylon, rayon, and cotton all compete as cords for garden hose, and the position of all three is endangered by the appearance of vinyl plastic hose which contains neither cords nor rubber. No doubt in the near future hose and sprayer will meet the competition of airplane and Dry Ice as man-controlled rainfall takes over.

The net result of this replacement of one material for another is economic progress. In your line of business it means greater military power. Creative intelligence is being applied to all business problems as never before. We are not only discovering new materials, but we are making progress in perfecting better ways to produce new materials, to the end that industrial progress is being accelerated. Let us hope that this trend can be extended into the future, since upon it depends our safety and prosperity.

Industry's search for new materials to produce has always involved finding a product which economically fills a need. Originally, the principal bottleneck to progress was the synthesis of new products, which appeared only rarely, whereas the needs of mankind were obvious and numerous. I suspect that the needs of mankind today are as numerous as ever, but modern advances in the physical sciencies have provided us with such powerful tools of synthesis that we can say with certainty that

the ratio of unfilled needs to candidate new materials has gone down. Industry is thus faced with a different situation. In order to maintain the most rapid rate of progress, it is becoming important to place emphasis on finding the use and defining the need for new products. Perhaps I shall be able to give you the best understanding of the evolutionary character of industry's continuing search for new materials if I adopt an historical approach to my subject, citing a number of specific examples.

Back in the nineteenth century, new materials arose mainly through the efforts of free-lance inventors working in their own basement laboratories. Generally, these men labored to meet well-recognized needs and followed in the footsteps of many others who had failed. Thus we all recall the famous experiments of Charles Goodyear and Nathaniel Hayward which gave us vulcanized rubber and made possible the production of rubber articles which did not become sticky over a wide temperature range. Experiments by Charles M. Hall, of Oberlin, Ohio, in 1886, uncovered an economical method for preparing aluminum by the electrolysis of alumina dissolved in molten cryolite and were mainly responsible for tonnage production of this lightweight metal. Experiments by L. H. Baekeland, between 1906 and 1910, aimed at finding a shellac substitute, failed in this objective but gave us heat-setting phenol-aldehyde resins. These are probably best known to you under the trademark "Bakelite." They found immediate application as an insulating material in the electrical industry.

Our rayon industry began in a similar manner. As early as 1855, Oudemars, a Frenchman, drew out threads from a pool of nitrocellulose solution, solidified them in air, and wound them onto a spool. Several years later, Ozanam, another Frenchman, spun a solution of natural silk through jets of various sizes and thus pioneered the extrusion method of filament formation.

It was not until about 1885 that Swan, in England, and de Chardonnet, in France, perfected methods for spinning nitrocellulose fibers and subsequently denitrating them to the point where the fiber could be used in textiles. But this did not establish the rayon industry on a firm basis, for no rayon is made by the nitrocellulose process today. It merely encouraged other free-lance inventors to attempt to find better and cheaper ways to form a regenerated cellulose yarn. It required a long list of such inventors and another 25 years--until 1911--to overcome the chief difficulties with the viscose process for rayon manufacture, the one now most generally used. It was not until about 1930 that the industry made a product comparing at all favorably with today's yarn.

Obviously, this route to new materials is apt to be slow and inefficient and has been largely replaced by methods which insure more rapid progress. However, new materials occasionally arise in this manner even today; witness the notable example of "Polaroid" film which stemmed directly from the personal efforts of Edwin H. Land.

Industrial research, as we know it today, was not possible until business institutions had grown to the size where they could afford to set aside sizable sums of "patient" money for the support of reaearch organizations and until fundamental researches in the colleges had provided a sufficient body of knowledge and the tools with which research men could make progress at a reasonable rate.

Thus, industrial research is pretty largely an innovation of the twentieth century. Du Pont opened its first formal research laboratory in 1902 at Repauno Works, Gibbstown, New Jersey. This was one of the first industrial research laboratories in the United States. A Central Chemical Department to engage exclusively in research was not established until 1911. Du Pont began fundamental research in 1927. The principal growth in industrial research has occurred during the past two decades.

One of the early preoccupations of industrial research was with an attempt to convert old products to meet known needs. This type of research was and often is a necessity if a firm is to continue in business. Two examples in point are the development of acetate rayon and "Duco" lacquers after the First World War.

At that time, rayon was in great demand, selling upwards of $5 per pound. The Dreyfus brothers in England, who had just placed in operation a large plant for the manufacture of cellulose acetate dope for airplane wings, were faced with a sudden collapse of their principle market. Consequently, an ample stake existed to warrant a determined research effort. They set out to develop a process for converting the dope to rayon yarn. A year later, they began offering samples of yarn to the trade only to find it rejected emphatically because it could not be handled on ordinary textile machines nor dyed with available dyes. Accordingly, they set out to perfect fabricating and dyeing techniques, which was accomplished barely in time to preserve for them financial control of their enterprise.

The stake in developing a quick-drying, durable lacquer was likewise enormous, for during the early twenties the finishing of automobile bodies constituted an impassable bottleneck in automobile production. Several weeks were required to apply and bake the various enamel coats required to finish an automobile body. The industry was crying for a finish which could be applied, dried, and polished in a few hours. The market for nitrocellulose likewise had collapsed with the termination of the war. Nitrocellulose lacquers which dried very quickly were known, but, due to the excessive viscosity of the then known nitrocellulose, they could not be prepared with high enough solids to make possible the application of a reasonably thick coat. The key to the solution of this problem was discovered by a du Pont chemist in our Parlin, New Jersey, plant, when he found that the viscosity of nitrocellulose solutions could be reduced by treatment with a small amount of sodium acetate. This discovery launched one of the swiftest tides of change ever to burst from a chemical laboratory. Following an intensive research program, the first Oakland car with the new finish was introduced in the

fall of 1923. By 1925 "Duco" was being applied to a majority of the automobiles manufactured.

Phenomenal progress was made in the basic science of synthetic organic chemistry during the first decades of this century. World War I, which cut this country off from its sources of organic chemicals in Germany, awakened our chemical industry to the possibilities of organic synthesis and touched off synthetic programs which have produced new chemical compounds at an ever-accelerating rate.

Lauren B. Hitchcock, of the Quaker Oats Company, has estimated that over the past 25 years the number of commercially available chemicals has increased by 450 percent, from some 1,500 to a current figure of about 8,250. He suspects that another 3,400 chemicals are being offered today in semicommercial, pilot plant, or experimental quantities.

These new materials have arisen by way of systematic studies of what could be synthesized from existing products, by-products, or cheap and readily available raw materials. The appearance of each new product and its by-products, if any, has created new possibilities for chemical synthesis. Thus, the possibilities increase, on and on, exponentially.

An illustration of how one product leads to another is provided by the accomplishments of Union Carbide and associated companies. A study of new ways to synthesize acetylene led to the production of ethylene and propylene, two other hydrocarbon gases, as by-products of the cracking of petroleum. Ethylene was converted to ethylene glycol which found a ready market in antifreeze and dynamite. A by-product, dichlorodiethylether--trade name "Chlorex"--found use in extractive distillation. Ethylene oxide which could be isolated from the glycol synthesis was converted into a number of glycol ether solvents and plasticizers sold under the trade names of "Carbitol" and "Cellosolve," and into polymeric ethers, sold under the trade name of "Carbowax." The ethanolamines, weak bases which have a wide variety of industrial uses, were formed by the reaction of ethylene oxide with ammonia. Vinyl chloride and ethylene dichloride occurred originally as by-products of the glycol synthesis and are now made as primary products. Vinyl chloride is polymerized into the plastic trademarked "Vinylite" which enjoys a large market today. Reaction of ethylene dichloride with ammonia led to a variety of diamines. This is only a partial list.

The oil industry has served as a most important source of cheap raw materials. Thus the Shell Development Company, seeking uses for propylene, learned how to substitute one of the hydrogen atoms by chlorine to produce allyl chloride. From this they produced synthetic glycerine, allyl alcohol, acrolein, diallyl ether, epichlorohydrin, dichlorohydrin, allyl esters, and so on.

Such extraordinary fecundity throughout the chemical industry soon became embarrassing. There were too many compounds and too few uses. It became necessary to devise systematic methods for evaluating the new

222

products and finding uses for them. I am proud to note that the management of the du Pont Company anticipated this problem before it became critical. They recognized that when one synthesizes a new compound it is very difficult to predict where it will find use. For example, it may turn out to be an insecticide, a plasticizer, a detergent, a dye assistant, or a delusterant for rayon.

They reasoned that a broad framework of commercial experience in the chemical field was needed against which to appraise the products of research. They set out to assemble such a framework by bringing several other companies into the du Pont organization and by the purchase of manufacturing processes from others. This phase of the company's development was complete in the early thirties. Without this diversity of business interests, it is doubtful if the du Pont Company could afford to expend anywhere near as much effort on the synthesis of new materials as it does now. As a result of this foresighted planning, the development of new products has flourished to the point where in 1949 they accounted for 54 percent of the assets of the company as compared with 12 percent acquired from other companies and 34 percent representing prior assets.

All chemical companies are consciously or unconsciously engaged in diversifying their businesses. When a new chemical with attractive manufacturing possibilities appears in the laboratory, the first step is to make a comprehensive study of its chemical and physical properties. These data are generally publicized first within the company to give the diverse manufacturing divisions an opportunity to examine the utility of the new material against their knowledge of existing needs. After internal evaluations have proceeded far enough to protect the interests of the company in its existing lines of business, the property data are generally disseminated widely in pamphlets and in publications in the scientific and trade literature. The trade is supplied with samples. It does not suffice, however, to sample the trade and then sit back and wait for something to happen.

All companies have been forced to set up sales development staffs to catalyze customers in their attempts to utilize new products, and in the later stages of development to estimate the extent of the market. These development sections are staffed by technical personnel, who work directly with the research or development people of the customer, to diagnose and help solve problems encountered in the use of the new product. Thus, when nylon was first supplied to the trade in sample quantities in 1938, our development people defined the problems involved in hosiery manufacture and worked out solutions to all of them, so that they could step into any hosiery mill and tell them how to make good nylon hose with reasonable operating efficiency. Just before the last war our development personnel assisted customers in making acceptable nylon parachutes. During the war, I recall that we assisted the rubber industry in solving serious problems connected with the fabrication of nylon bomber tires and self-sealing gasoline tanks.

Many industrial laboratories have been set up to engage exclusively in this type of activity. These laboratories are usually equipped with small-scale manufacturing equipment on which it is possible to pilot operations carried out in customers' plants. Two new technical societies have been formed to promote sales development and technical service activities: The Chemical Market Research Association, founded in 1945, and the Commercial Development Association, organized in 1947.

New types of sales staff and salesmanship have arisen from these activities. The new product is sold on merit and performance. The same scientific approach which was required to originate the product is now required to learn how to use it and to demonstrate its value. Men are required who know how to diagnose difficulties, how to plan experiments so as to collect significant data, and how to analyze the data to draw valid conclusions.

Mention was made previously that it was fundamental research in the colleges that paved the way for this proliferation of organic chemicals by industry. In the late twenties, it became apparent to C. M. A. Stine, who headed the Central Chemical Department of du Pont, that the pace of industrial progress could be accelerated if industry would supplement the fundamental research of the universities with fundamental research of its own conducted in carefully chosen areas of science where there existed an obvious industrial need for basic knowledge.

For example, at that time there was great debate as to the chemical structure of natural substances which we now class as polymers, that is, of cellulose, starch, rubber, silk, and so on. Methods for the synthesis of high polymers were notably lacking. Du Pont, with business interests in rayon, nitrocellulose, coated fabrics, coating compositions, and so forth, could obviously profit by additions to scientific knowledge in this field. Accordingly, Wallace Carothers, a young professor of organic chemistry of unusual promise, was engaged to conduct fundamental synthetic studies in the field of high polymers, and other fields. This represented a new evolutionary step in industry's approach to the problem of searching for new materials.

The researches of Carothers and his group were phenomenally successful. In a few years they had developed methods which enabled them to synthesize long, chain-like molecules having properties of the type formerly found only in such natural polymers as cellulose, rubber, and silk. Their efforts opened up a whole new field of synthesis for the industrial organic chemists. From the host of polymers which these men put together in the laboratory, two were selected for commercial development--one was nylon, the other neoprene.

Advances in physical chemistry during the past 25 years are placing us in an increasingly better position to relate the properties of a material to its chemical structure. For example, in my own field we can pretty well account for the high strength, elasticity, toughness and

softness of nylon, the stiffness and resilience of "Dacron" polyester fiber, the fatigue-resistance of tire-cord rayon, and the crimping characteristics of our new Fiber E from the known structure of these fibers. As the quality and quantity of such knowledge increases and as advances in organic and inorganic chemistry give us ever greater opportunities for synthesis, we find ourselves in a better position to "tailor" new materials to fit a given need. This in turn should increase our rate of progress.

This brings me to the last point I wish to raise in connection with industry's evolving search for new materials. In some cases the need is not well-defined and before one can set out to synthesize a new material one must do fundamental research in order to define the need. We find ourselves in that position today in the textile industry.

Our new synthetic fibers have properties radically different from any fibers which have gone before. Everyone agrees to the merits of some of these properties, the durability of nylon to wear, the resilience of "Dacron" polyester fiber, the resistance of "Orlon" acrylic fiber to deterioration by sunlight, and so on, but when one gets around to the subject of comfort of the garments, one runs squarely into a most confusing situation. Some will tell you that nylon garments are hot; others will tell you they are cold. Some insist that high moisture absorption is essential to comfort—these fibers have low moisture absorption—yet I traveled on the desert this summer clad only in nylon and "Dacron" and was surprisingly comfortable at 100°F. plus. Our Development Section has scoured the country to find out what knowledge is available on the fundamentals of clothing comfort. Plenty of prejudices exist, but practically no scientific knowledge exists.

It seems to us that there are two steps to be taken toward closing this gap in our knowledge: (1) the characterization of all kinds of fabrics in all kinds of constructions by a study of heat transfer through them under a wide variety of environmental conditions, and (2) a comprehensive wear-testing of garments made from carefully selected fabrics to determine their wearing comfort, not only by subjective reaction, but also by physiological measurements of skin temperature, skin wetness, and perspiration loss. So we have set up a long-term project of this kind. From the results of this study, we should be able to define what is needed to provide comfortable clothing for any climate. Perhaps this will encourage us to synthesize a new fiber; perhaps it will only tell us how to use our existing fibers more intelligently. In either case, these fundamental researches should have defined the problem to the point where we can do something about it.

By now I hope that you will have noted that many approaches have been evolved to this problem of searching for new materials; all are in use today. I also hope that you have gained the impression that this search has become a major effort for wide segments of American industry. It constitutes one of the major forces of change, aimed in the direction

of greater industrial might and a higher standard of living. This activity has greatly enlarged the scope of competition to the point where the consumer now chooses between different products and different industries rather than between merely different producers of the same product. Today, industrial firms compete not only in the market place but also in the laboratory.

I have not touched upon two points mentioned in the scope of my assignment: (1) how research objectives are selected and research effort apportioned and (2) the relationship of chance and deliberate endeavor in reaching an industrial research objective. Let us devote the remaining time to a discussion of these points.

The choice of research objectives and the apportionment of research effort are primary concerns of research management about which it is not easy to draw valid generalizations which are particularly informative. It occurs to me that this problem must have many points in common with the problem you face in the choice of military objectives. There are innumerable worth-while objectives, but the problem is to choose the most worth-while objectives to attack with the limited research budget, facilities, and personnel available. One must balance potential gain against probable costs. One must plan for the future while at the same time protecting the health of the existing business. One must concentrate sufficient power in the attack on specific projects to insure a favorable decision, yet one must not stake everything on the outcome of one attack.

Most research directors aim for a degree of balance in their programs. A certain proportion of the effort is directed toward long-range objectives. This scouting and fundamental work turns up the new products which will be developed some years hence. Then a sizable proportion of the program is directed toward insuring the health of the current business--primarily quality and cost improvement studies. Finally, the balance of the effort is concentrated on the development of a limited number of carefully chosen products which are carried through to a decision to commercialize or not to commercialize as rapidly as possible. I presume it is this latter group of objectives which interest you most.

One of the toughest problems is to find out what are the important needs of our day, so that these can be used to guide the synthesis of new materials and their evaluation. Some progress has been made in this direction. One of the important duties of modern sales staffs is to know their customers' businesses and their customers' customers' businesses down to the ultimate consumer needs and know them so well that they can report back important needs to the research staff. Another approach is to comb the trade and technical literature. Development sections frequently make industrial surveys, industry by industry, aimed at uncovering their more important needs. Even assuming that the need is known, before one can justify venturing large research expenditures one must determine: How real is the need? What price can be

attached to a new material meeting the need? What volume might be sold? Are there alternative solutions?

It is easy to collect opinions, but what are the facts? We have much to learn about getting answers to these questions!

On occasion I have greatly oversimplified the problem of selecting development objectives by saying that the desirability of undertaking such a project is proportional to the stake to be gained, multiplied by the probability of success, and divided by the probable cost of the investigation. The way to choose a development program is to arrange the candidate projects in order of decreasing desirability by the aforementioned index and to tackle those at the top of the list which can be brought to fruition within a reasonable length of time with available manpower and facilities.

I believe this is an acceptable approach to the problem, but its description in these terms may provide considerably less clarification of the subject than is at first apparent. For example, the stake in developing a product will vary from company to company. Projects with a high index of desirability for a concern with large resources may actually be of no interest at all to a small firm without the resources necessary to bring them to fruition. If a company is short of capital, it may be more important to develop new products which can be manufactured on existing equipment than products which require new plant investment. One company may be favorably situated to use or dispose of by-products, whereas another may not. One could go on indefinitely with special considerations which can assume controlling proportions.

A period of seven years has been widely publicized as the time required to carry a product from the test tube stage to commercial production. There is a tremendous stake in shortening this period of time, for success with a new product, like success in war, often goes to the one who arrives "firstest with the mostest." This encourages research management to confine its attack to a limited number of development problems at a time. It is better competitive strategy to excel in a few lines than to trail in many.

A further reason for concentration of the attack stems from the fact that successful developments go through a period of peak expenditures and occasional periods of crises which may severely tax the resources of the group. The early laboratory stages are relatively inexpensive. As soon as samples are distributed to the trade, expense begins to mount. The samples will generally be produced in improvised equipment, often poorly adapted to the special requirements of the particular synthesis involved. No acceptable synthesis may be in hand at this stage of the development, though the odds must be good that such a process can be worked out. In the small-scale equipment available, the product may cost $10 to $50 per pound to produce--perhaps twenty times ultimate costs.

As soon as evidence begins to accumulate that uses will be found for the product at sales prices likely to permit production, research tempo is speeded up. Chemists and engineers are assigned to develop a commercial process. The immediate goal is the construction of a pilot plant which incorporates all of the features essential to the economical production of a quality product when the plant is scaled-up to full size. While this is going on, sales development will be working with more and more customers, perfecting ways to handle the product and attempting to estimate what the product will be worth and how much can be sold.

At frequent intervals the economic analysis boys will examine the process being developed by the engineers and will estimate investment costs, production costs and probable earnings at prices and volumes estimated by sales development.

Research costs hit a peak during operation of the pilot plant. The product is generally sold to customers at a price approximating that which will later be charged when in full-scale production. Operation of the pilot plant makes it possible to firm up cost estimates, enables the engineers to take the final bugs out of the process, and gives the customer enough product to make possible a much more accurate estimate of possible markets.

At some point in this sequence a decision is made to commercialize or not to commercialize the product; if in the affirmative, the costs really begin to mount. The product enters the "shirt-losing stage." For now plant design begins. Plant construction starts before design is complete. Pilot plant operation is generally set up as a separate enterprise, with its own sales staff, operating staff, and research staff. Each month the operation turns in a resounding loss, but each month the process and market should be more firmly established. The course of most developments is anything but smooth. Crises arise which have to be met and solved in time intervals which seem much too short for the task. Somehow these difficulties are overcome. Just as in the military world, some of our best flashes of genius and most effective solutions to problems arise in the heat of battle! The pilot plant operates right up to the time that production begins in the full-scale plant and sometimes for an interval thereafter in order to assist in the diagnosis of difficulties which arise at the time of plant start-up. If the job has been well done, the product will soon begin to support itself. All will breathe easier. Yes, the trials of launching a new industry, like those of parenthood, are conducive to moderation in the number of products undertaken for development at any one time!

This brings me around to the last point which you asked me to discuss—the relationship of chance and deliberate endeavor in reaching an industrial objective. You have indeed posed a pertinent question! There is far more chance involved in this research business than we like to admit. In fact research is always a gamble, one with rather poor odds of success. I believe Crawford Greenewalt has estimated these odds

as averaging about 5 percent for any given research project. Of course, the whole evolution of modern industrial research has been sparked by an effort to improve the odds of success, but chance still plays a large role in research in spite of all that we have done.

Ed Spanagel, who had a large hand in the nylon development, once pointed up this fact in a very revealing fashion by the remark that, "A theory is a good one if it tells you to do something. It is a bad one if it tells you not to do something." In other words, we grope in the dark so much of the time that mere experimentation is preferable to inactivity because it increases the odds of success.

I was very much interested yesterday afternoon at the main lecture at the International Congress of Pure and Applied Chemistry in New York to hear Professor Todd state the same thing--that is, he said a hypothesis is a good one if it tells you to do something. I suspect that if we ever succeed in improving the odds in research to the point where the chance of success is much better than the 5 percent which Mr. Greenewalt has mentioned, we shall then tackle tougher problems so that the odds will go back down again. It is a game you can't win!

I suppose the odds of success are more critically related to the creative ability of the research staff than to any other one factor. We must never forget that it is people who conceive the new ideas and make the inventions, not fine laboratories or equipment. As technical processes have become more and more complex, it has been found necessary to employ a great percentage of men with advanced training. This is true throughout the chemical industry. And there are not anything like enough Ph.D.'s to fill the demand. It is to that one percent of United States labor, our scientific manpower, that we must look for the vital and essential ingredient upon which depends our future growth, stability, and security. One of the most important problems which you and American industry face, and in fact all of us must face, is how to insure the training of larger numbers of better scientists.

I dwell upon this fact because I was alarmed by some statistics recently called to my attention by our Personnel Section. These indicated that military research engaged 47 percent of the scientists carrying on research in this country in 1950. The current military budget is expected to engage 70 percent of the supply. In calling this to your attention, let me hasten to add that as a research man, a citizen, and a taxpayer, I am very pleased to see the armed forces become so interested in research. If I could have made the decision, we would have had a large military research budget ever since World War I. However, unless there is some corresponding increase in the number of scientists trained, this sudden expansion in military research can have disastrous repercussions in industry. We could end up a weaker instead of a stronger nation.

So far as I can determine, there is every prospect that, in the near future, fewer rather than a larger number of scientists will be trained by our colleges. The seriousness of this problem was pointed up by a study of the Engineers Joint Council, published in June of this year, which indicated that after this year's graduating class of 38,000 engineers was absorbed there would remain an unfilled demand for 60,000 more. The 1952 graduating class is estimated at 26,000; the 1953 class at 17,000; the 1954 class at 12,000. The same situation exists with respect to all other scientific students.

Many technical people now employed are subject to military recall. Out of 375,000 scientific and technical people employed in industry, an estimated 100,000 are Reserve officers or are otherwise liable for service. About 65,000 are of draft age—19 to 25.

I do not pretend to know the answer to this question, but I am in a good position to recognize its seriousness. It would seem that drastic action should be taken in the very near future to insure an ever-increasing supply of young scientists. This is no time to fall behind in what may ultimately provide the means of survival.

Since writing this paper there has appeared in "Fortune" magazine an article entitled, "A Helluva Shortage of Engineers." I commend it to your study if you would like to delve into the problem a bit. The author seems to have the facts and considers the problem most vital. Most articles in "Fortune" are temperate in tone; this verges on being intemperate.

Having called this most vital problem to your attention, I bring this discussion to a close. You will have noted that there is nothing very startling about industry's search for new materials except perhaps the newness and magnitude of the effort. In the last analysis, all of our research comprises an orderly scientific attempt to discover ways to accomplish more with the expenditure of less human effort. You must face the same sort of problem in your planning to achieve greater striking potential from less manpower.

QUESTION: Doctor, I wonder if you would explain to us a little of the background regarding the emoluments that a man going into an industry might receive—since we live in a competitive system in which that has to be applied—I mean to say a man going into an industry as a Ph.D. or the harness making business; also how many? Would you develop that theme for us?

DR. HECKERT: Of course I only know our own situation. Our personnel people make studies all the time and keep adjusting the starting rate. I presume that is what you are talking about.

QUESTION: The entire situation. What a journeyman would expect after 20 years, for instance.

DR. HECKERT: The starting rate for a Ph.D. has been adjusted upward, upward, upward. It is now about $475 or $480 a month for a man with no experience, I believe. That figure is being constantly studied. I suppose most companies do the same as we do. Continuing studies are going on all the time within the company; these studies try to keep the right relationship between the wages and salaries of people doing different kinds of work. Ph.D.'s are part of that study.

I might say, though, in our research force, although we hire Ph.D.'s at considerably more than we pay to a four-year man, 10 or 15 years after they have been with us, that distinction pretty well disappears. What becomes more important is how productive a man has been. You begin to forget about his training.

Now I think it is fair to say that in the research business, in our company at least, the Ph.D.'s make out better, on the average, and get further than the four-year man, but that, I think, is only because they have been through a screening device of four more years of college. So you aren't starting with a fair sample. Many of the four-year people aren't research people and never will be so they go out and take operating jobs or sales jobs. I don't think this comparison means very much. I don't know whether that answers your question or not. I don't believe it is possible to answer it any better.

QUESTION: Dr. Heckert, you know that the textile manufacturing industry over a period of years has never come out with any startling improvements that would increase its production capacity over the past 60 or 70-odd years. By the development of new synthetics which go into fibers, in your processing of those fibers into fabrics in your laboratory, have you made any effort at working with the textile machinery industry for improvement in the design or new type of manufacturing equipment to give us an increased productivity?

DR. HECKERT: Well, we have chipped away at that problem. There have been a good many attempts to improve existing machines to help them do a better job. You are asking have we worked with equipment producers in a radically new way. The answer to that is no. Maybe it is because we just haven't had any very good ideas.

QUESTION: Doctor Heckert, you mentioned your study of the comfort of textiles. Is there any connection between your private organization and the military services on such research, any coordination which will benefit us in the use of textiles in the armed forces? I simply use that as an example. I am wondering whether there is any coordination between private research organizations and this tremendous amount of money the Government is spending. It might be that we could take as an example an engineering laboratory that might be working independently on atomic energy. I know they do coordinate with the Government on it. Do the others in any way?

DR. HECKERT: Consider this comfort study—it is a good one. We are taking the position that we are going to tell everybody about it. Any investigators from any research laboratory are welcome to talk over the problem with us at any time. As a matter of fact, some of the scientists from your Quartermaster group have been through our laboratory within the last two weeks and we compared methods for measuring and recording skin temperatures, and so on. We have had help from your people and they in turn have had a little help from us. We intend to make our information freely available.

QUESTION: It is my impression that in certain fields of industry, the automotive industry, for example, there is a certain reluctance on the part of manufacturers to adopt radical changes in design due to retooling costs. Is that true in your industry and do you have the problem of retooling?

DR. HECKERT: As for the automotive industry, I know nothing about it although I can appreciate the retooling factor. I don't recognize that as a serious problem to us. Every time you come along with a new fiber, it takes something a little bit different to handle it. For example, in the case of nylon, one of the things you have to do is "heat set" the fabric. That costs the textile people more money. There is a certain reluctance to install the necessary equipment to do that. Somebody started off and pretty soon everybody was doing it. I guess our retooling cost—if you want to call it that—has been very small and it hasn't been recognized as a very serious problem.

QUESTION: What is your coordination with European research organizations?

DR. HECKERT: There is no coordination except by way of the exchange of information through the scientific periodicals—that sort of thing—meetings like the International Congress of last week where a lot of people from abroad talked over basic problems together. But there is no coordination.

QUESTION: We have been told that Germany practically led the world in research in the prewar period, in the twenties, and in the thirties. I have been led to understand that Russia did all it could to try to get all the scientists, Ph.D.'s, whatever you wish to call them, into Russia. I do know that Wright Field got a number of them. I know that in the European theater we tried to get as many as possible, mostly for the armed services. What did industry do in getting some of those Ph.D.'s to work in private industry, such as du Pont, possibly G. E., Westinghouse, and some of the other big developing concerns? Did they miss the boat a little bit like the military did in getting important generals and admirals and ship them across the sea to enlighten us on their methods of warfare?

DR. HECKERT: I suspect we missed the boat to a considerable extent. It is true that a number of the men with international reputations came to this country. I think in many cases they have located in colleges, and then industry has hired some of them as consultants. To that extent we didn't miss the boat. Right at the moment we are attempting to hire some young scientists in Europe for the Rayon Department. We haven't done too much of that.

QUESTION: How does a firm like du Pont determine how much goes into fundamental research and how much goes into applied research?

DR. HECKERT: That is purely a matter of judgment. In the case of du Pont, we are very widely decentralized. We have a Central Chemical Department that does most of the fundamental research. It is broadly responsible for the future of the company. It spends most of its budget on fundamental research. The rest of us--a dozen or so operating departments--each has its own research organization, and the research director uses his own judgment as to how much to do.

QUESTION: I would also like to ask, in your judgment, where would be the proper place for fundamental research emphasis? Is it in private industry or is it in the colleges and universities?

DR. HECKERT: Oh, in the colleges and universities; there is no question about that. I don't think industry can ever hope to do it all. For one thing, you want the decentralization and freedom of the university for fundamental research; no one can predict where it is going to go, where the advances are going to come.

MR. SWAREN: You spend a lot of money in your research operations. What protection do you have that this is not pirated by one of your good friend competitors?

DR. HECKERT: Well, if it involves an invention, it is supposed to be new and it is supposed to be useful; it is supposed to involve a flash of genius. If it is considered an invention, you can apply for patent protection. Then, if you are awarded that patent, for a period of 17 years you have the exclusive right to use or to license other people to use that invention in return for disclosing the invention to the public. It is just a deal between the Government and yourself--you disclose the information in return for a limited monopoly of 17 years. At the end of that time anybody is free to use it. Of course, if you can't get patent protection, if the invention is not patentable, you have no protection.

QUESTION: Do you consider advertising spent in establishing a name like Kodak or nylon is much protection? I would like your opinion because you are on the dollars and cents end of that and some of us like to think of it occasionally.

DR. HECKERT: Well, maybe it would be appropriate to point out that when we invented the name "nylon" we did not make it a trademark and when we came along to "Orlon," we did. So you can see how much agreement exists on that.

QUESTION: Speaking of research budgets, our present excess-profits-tax laws apparently make it possible for a company such as du Pont to carry out research on 18 to 20 cents on the dollar, the Government paying the rest of it. Has that factor affected your research business?

DR. HECKERT: It certainly hasn't affected mine. Our management forgets all about this excess-profits-tax law and says, "What is sound one year, is sound another year," and we have to conduct our business in the same fashion regardless, so that has not been reflected at all.

QUESTION: What about smaller industries?

DR. HECKERT: I can't speak for others. I suppose there are some people who take advantage of it.

MR. SWAREN: Dr. Heckert, it is a pleasure to thank you for your talk, and I am particularly happy that you not only have tied up my particular interest of prospecting but you have also tied up Colonel Seaward's interest of the impact on society. On behalf of the college I thank you.

(28 Nov 1951--650)S/RSB