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RESEARCH AND DEVELOPMENT WITHIN INDUSTRY

27 February 1956

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GENERAL DISCUSSION 25

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Mr. E. Duer Reeves, Director and Executive Vice President, ESSO Research and Engineering Company, was born in New York City in 1909. He graduated from Williams College in 1930 with a B. A. degree and did graduate work at Princeton. He left Princeton in 1930 to join the staff of the Standard Oil Company (New Jersey) and has been with various Jersey affiliates since that time. His first assignment was with Jasco in 1935 and in 1936 transferred to the research and development laboratories of the Standard Oil Company of Louisiana. In 1937 Mr. Reeves moved to the Research Division of the ESSO Research and Engineering Company (then called Standard Oil Development Company) at Bayway to take charge of its newly formed Process Development Section. In 1945 he became Director of the Research Division. In 1947 he was appointed Director and Vice President of the Company in New York City and has been Executive Vice President since January 1949. Mr. Reeves is President of the Industrial Research Institute and Vice Chairman of the National Association of Manufacturers Committee on Research.

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GENERAL CALHOUN: The percentage of the sales dollar going into research and development has become in recent years one of the accepted indicators of the future health and competitive position of the corporation. Industry derives its dynamic strength and its ability to react quickly in peace or war from vigorous research and development and technological know-how. The "help wanted" columns in our newspapers gives an indication of the demands of industry for personnel who are qualified in this field.

Our speaker has been connected with research and development for the past 25 years. He is Mr. E. D. Reeves, Director and Executive Vice President, ESSO Research and Engineering Company.

Mr. Reeves, it is a privilege to have you back at the College and to present you to this class. Mr. Reeves.

MR. REEVES: Thank you very much, General Calhoun. General Hollis: I am very happy to be back here again. I have enjoyed coming here for a number of years now because it gives me an opportunity to talk about something very close to my heart, that is research and development work. It is something I have been doing for about 25 years. In the time I have been connected with it, I have seen it grow from a practically insignificant activity to one where it is responsible for the vastness of the competitive strength of industry in this country.

In the first place, I would like to say that industrial research as we know it today is not something that is supported by industrial concerns or carried out as a separate activity just in the hope that something good will come of it but is a truly integral part of industrial activity in this country. When I first started to do research back in 1930, industry in the United States was spending about 200 million dollars annually for its research and development. Since that time, this effort has grown tremendously, to the point where today three billion dollars represents the current annual bill for industrial research and development work. This is a fifteenfold expansion in just the last two decades and clearly indicates the growing acceptance of research and development by American industry.

I am in the liquid-energy business and represent an industry that has steadily grown because of research and is typical today of the interdependence of industrial growth and a closely coordinated research and development effort. You should also know that the industry I represent is by no means exceptional on this account. In fact, we are about average. There are quite a few industries in this country that put less emphasis on research and development; but there are also many who place even greater stress on it than we do, such as the chemical industry, the electronics industry, etc. In talking to you today about research and development within industry, therefore, I hope you will look on my own as a typical industry and will understand that as I talk about it I am also talking about a relationship between industry and research and development that spreads all through industry in America.

As we examine the broad subject of research and development in industry, it seems to me that there are four things we should consider today. The first is the question of just what industrial research actually is and how a typical business, the energy business, has grown through it; next, I would like to cover something of how we go about organizing and managing industrial research; thirdly, the kinds of things that can be accomplished through it; and, finally, the meaning of all this in terms of national security.

Coming to the first question of industrial research and what it is, I would like to start by saying that it is not the glamorous activity many people seem to think it is. Industrial research is a business activity and is carried on by modern industrial corporations to improve their competitive position. Industrial research is just as integral a part of what an industrial concern does as sales, manufacturing, or purchasing. Industrial research has to participate in the day-to-day decisions of the company of which it is a part, and as a member of the industrial team has very definite objectives and responsibilities.

One responsibility of a research group is to find out just what its company needs in the way of research results. It has to understand the problems of the people who use the products of its particular industry; it has to find out what kinds of products would suit their purposes best and what kinds of products they are likely to want in the future. It must also study carefully the manufacturing operations themselves to discover where these need to be improved and where work must be concentrated to match similar activities on the part of

competitors. Research has to go even further and study the raw-materials situation in view of the demands for new types of products, the possibility of lower costs, alternate raw materials, and the like. At the other end of the scale, there are numerous marketing problems that need to be looked at and possibly improved. In other words, every phase of the company's business has to be studied objectively and imaginatively to see where the raw-materials situation can be strengthened, manufacturing operations improved, products tailored to fit the needs of the people who buy them, and new products and markets developed to replace old ones and to help the business in its growth.

After all this has been done and the research organization has a pretty good idea of just what is needed in the way of research results, its next responsibility is to produce the results indicated. This part of a research department's activity is what most people think of when they think about research. It is obviously a very important part, because it does no good to know all about what is needed if methods cannot be developed to meet the needs indicated.

The third objective and responsibility of industrial research is to help other units in the company in putting research results to work. The real test of industrial research lies in its usefulness, and again I would like to emphasize that finding out that a company needs a particular product and then developing that product in the laboratories is not going to do the company much good unless all of this effort results in that product's being made and sold so that the company can maintain its business and make a profit. I mention all these things because we in industrial research have learned that, if we are to do effective work, we must spend a lot more effort than most people realize on the coordination of research with other activities and in doing all we possibly can to help the rest of the company in putting the results of research to work.

I think it is clear from what I have said that the real key to successful industrial research is the day-to-day participation of the research group in the formulation of a company's major policy decisions. Technology in industry is not a thing apart but is more a point of view or a way of doing business. In an effective industrial effort, you cannot really separate technology from other phases of the business.

When carried out in this way, industrial research can be an extremely powerful tool for industry and for all of us. The energy

business is a striking example of what can be accomplished through industrial research and of how, even in a short period of time, the results of research can affect our whole way of living. The energy business was really born in 1760 when James Watt invented the steam engine. This, as you know, was also about the time the Government of the United States was being formed. This was less than 200 years ago, and in comparison with all the years that man has been on this earth and struggling to improve his existence, it is as though this tremendous change, which was to completely alter his life, occurred overnight.

During these 200 years, the industrial revolution started by the steam engine was to go through a long period of incubation. For the first 90 years, the use of mechanical energy went through a sort of demonstration period. Steam locomotives were built during this time, some houses were heated with natural gas, and on a small scale, people were learning about the new type of servant they had just invented--the mechanical servant.

The limited use of this type of energy in the United States at that time is best illustrated by the almost incredible fact that in 1814 only 22 tons of anthracite coal were mined, and even in 1820 the bituminous coal industry had only progressed to an annual rate of 300 tons. By 1850, however, the industrial revolution was beginning to have a real impact. By then, over two million tons of coal were being mined each year, and in 1859 the oil industry with its liquid and gaseous forms of energy began its development with the Drake discovery well in Pennsylvania.

By this time, people had begun to realize the great potentials in using mechanical energy instead of horses and men to perform work, and there was a really rapid development over the next 50 years. As rapid as it was, however, it pales to insignificance when compared with events of the last half century. It has been calculated that of all the mechanical energy developed in the world from fossil fuels, such as coal and oil, almost 85 percent has been generated since 1900. In other words, our use of energy almost during our own lifetime has been six times the amount of energy consumed by all our ancestors. Accustomed as we are to central heating, powerplants, automobiles, electricity, and all other forms of mechanical energy, it is hard to realize that the energy story is in reality the story of an amazing turn of events that have taken place only within the last 50 or 60 years.

As we look back over what has so far been accomplished, we must be continually amazed at the rapidity with which these changes have taken place. The facts are, however, that in the United States in 1850, only 6 percent of the energy used by man came from machines operating on fossil fuels. The rest was supplied by man himself, horses, and other animals. By 1900, 38 percent of the work being done came from various fuels, and today coal, gas, and oil, with an assist from wood and waterpower, supply 95 percent of the energy that supports our civilization. Among other things, this has increased man's productivity some sixfold over what it was in 1850. Whereas in 1850 almost two-thirds of our working population were still required for farming, today less than 12 percent of the workers in the United States are needed to feed the entire Nation. If we add it all up, there has been developed in the United States, almost during the last 50 to 60 years, an economy based on the energy supplied by coal, gas, and oil operating through all sorts of machines that day in and day out lets each one of us do as much work as 200 men could do before man learned to harness these mechanical horses. Each one of us today has 200 mechanical men at his beck and call 24 hours a day and enjoys a standard of living in many ways superior to that of even princes of the past.

I hope that, as you listen to my remarks on the energy story, you will understand that I am not claiming everything that has happened over the last 50 years for the energy business nor for its research and development activities. I am sure it is perfectly obvious to you that the people concerned with the development of our energy resources did not also design the steamships, automobiles, and airplanes, nor did they invent all of the appliances and products pouring from our factories throughout the Nation. All of these things I have mentioned, however, do depend on the availability of energy--energy produced from fossil fuels such as coal, gas, and oil. So I think we can say that the energy business, although only a part of the overall effort, is the keystone and that without the availability of mechanical energy very few of the things that we regard as a normal part of our daily life would exist and be the commonplace characteristics of life in the United States that they are today.

The most vigorous phase of our energy business has been the development of what we call liquid energy. These are the petroleum products--gasoline for automobiles and airplanes; diesel fuels for railroads, ships, and trucks; and heavy fuels for the power industry that furnishes light and electrical energy. The liquid-energy business

has from the beginning relied on research, and its growth is characteristic of a coordinated blending of an aggressive research program and business initiative. This is an important example of research and development within industry, and I think you will be interested in knowing something about what is involved in carrying out research on liquid energy and in hearing of some of the things that are being accomplished.

The liquid-energy business is about as complex a business as you can get into. It involves an unceasing search for crude oil wherever it may be hidden--thousands of feet or even miles under the ground all over the world. Once it is found, we must then solve the problem of getting it out of the ground, transporting it to the refining centers, converting crude oil into the kinds of liquid energy we want, and then distributing these products to those who use them. Furthermore, as the machines that use energy are constantly developed and improved, the liquid-energy business has had to develop new products of its own so that each new machine can get the most possible benefit out of the liquid energy poured into it. These machines must also be lubricated to cut down on friction and wear. Another problem of our business has been to provide all of the special lubricants, greases, etc., needed to do this job. Finally, this same industry has recently found that the raw materials that are so useful in providing energy can be put to other uses, and we are rapidly developing a new phase of our business in which petroleum products come out of our refineries as all sorts of chemicals, plastics, synthetic rubber, solvents, and other specialty products. This, briefly, is the field in which we do research and development.

The organization of a research and development group to meet the various objectives I have outlined and to deal with all of the problems encountered in an industry such as ours is not a simple one when it is also realized that research and development work itself is a complex activity in which it is necessary to carry out fundamental research on the physical and chemical characteristics of the materials with which we deal, applied research on the application of these principles to the development of products, and pilot plant and engineering work required to translate all of this information into practical operations. I think you can see that the proper organization and coordination of this effort is a critical factor in its success. Research and development in my own company is carried out by a separate corporate organization which does the work for the Standard Oil Company (New Jersey) operating affiliates all over the world.

In order to illustrate some of the things that are involved here, I would like to show you our organization chart.

Chart 1, page 8. --I do not intend to go into this in any detail, but I just want you to see that a research organization today is made up of a great many different kinds of activities and a great many different kinds of people. This chart represents an organization of over 4,000 men and women. The research and development work itself is carried out by laboratories located in Linden, New Jersey; Baton Rouge, Louisiana; Houston and Baytown, Texas; Tulsa, Oklahoma; Sarnia, Canada; Port Jerome, France; and London, England.

You will note that in addition to laboratories, there are a great many other activities that have to be carried out. Contract, legal, and patent work, for example, is extremely important to us since it is necessary to protect our operations from suit by others and to collect royalties, which help support our research. I would also like to call your attention to the fact that a large research organization has to maintain its own library, its own business offices, a medical department, a personnel department, a public relations department, and in general carries out all of the business activities that are part and parcel of any corporate activity.

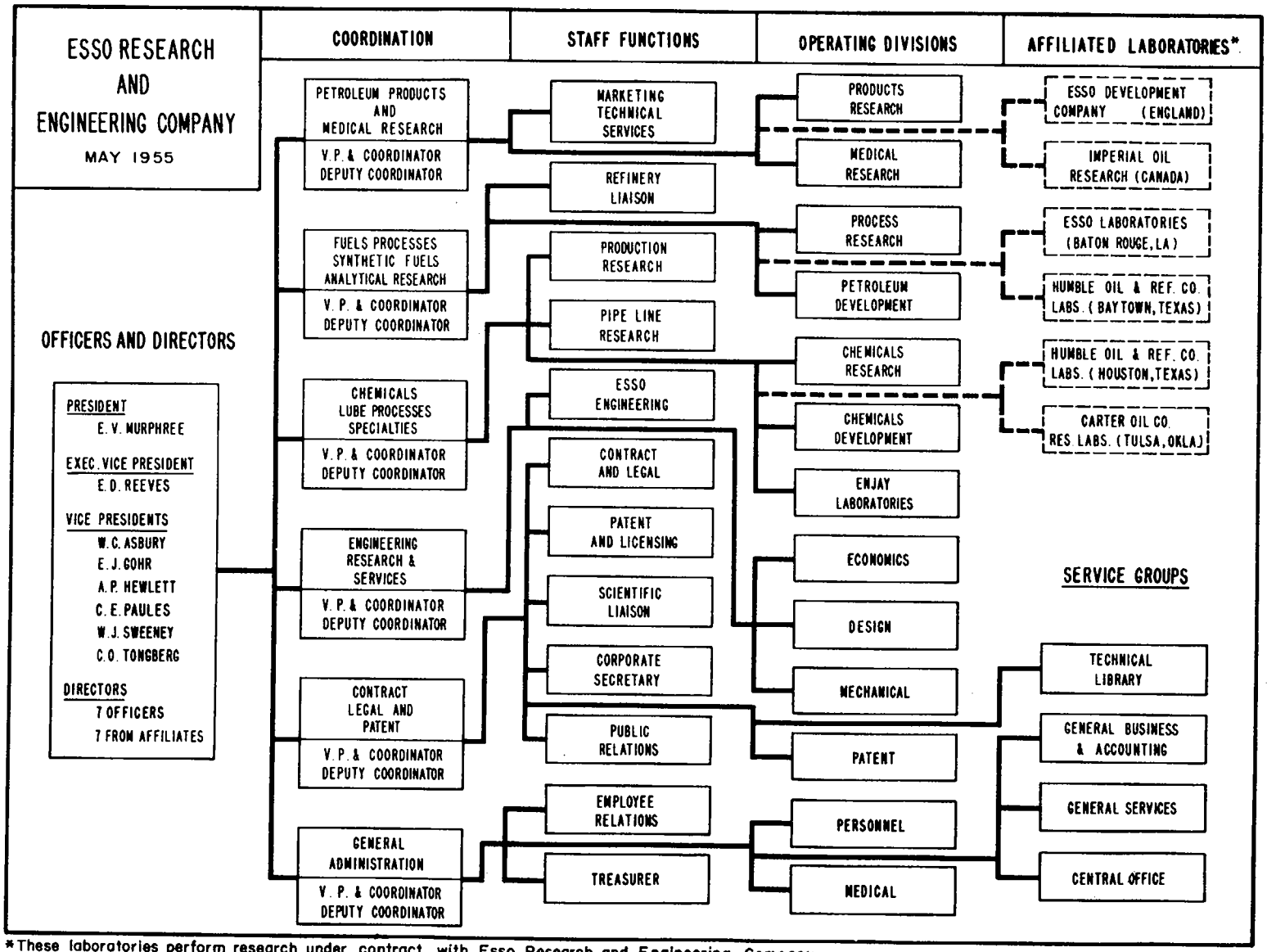
In addition to an organization, you also have to have facilities to carry out effective research and development, and I would like to show you a few charts illustrating some of these. The next chart shows our Research Center at Linden, New Jersey.

Chart 2, page 9. --This laboratory houses over 600 people and is fully equipped with all of the most modern facilities to assist our technical people in carrying out their work.

Chart 3, page 10. --This chart gives you some idea of the kind of equipment in one of the laboratories.

The evaluation of products we develop is extremely important since these have to perform satisfactorily if our affiliates are to retain their business. Our products are evaluated in all sorts of

CHART 1



*These laboratories perform research under contract with Esso Research and Engineering Company

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CHART 2

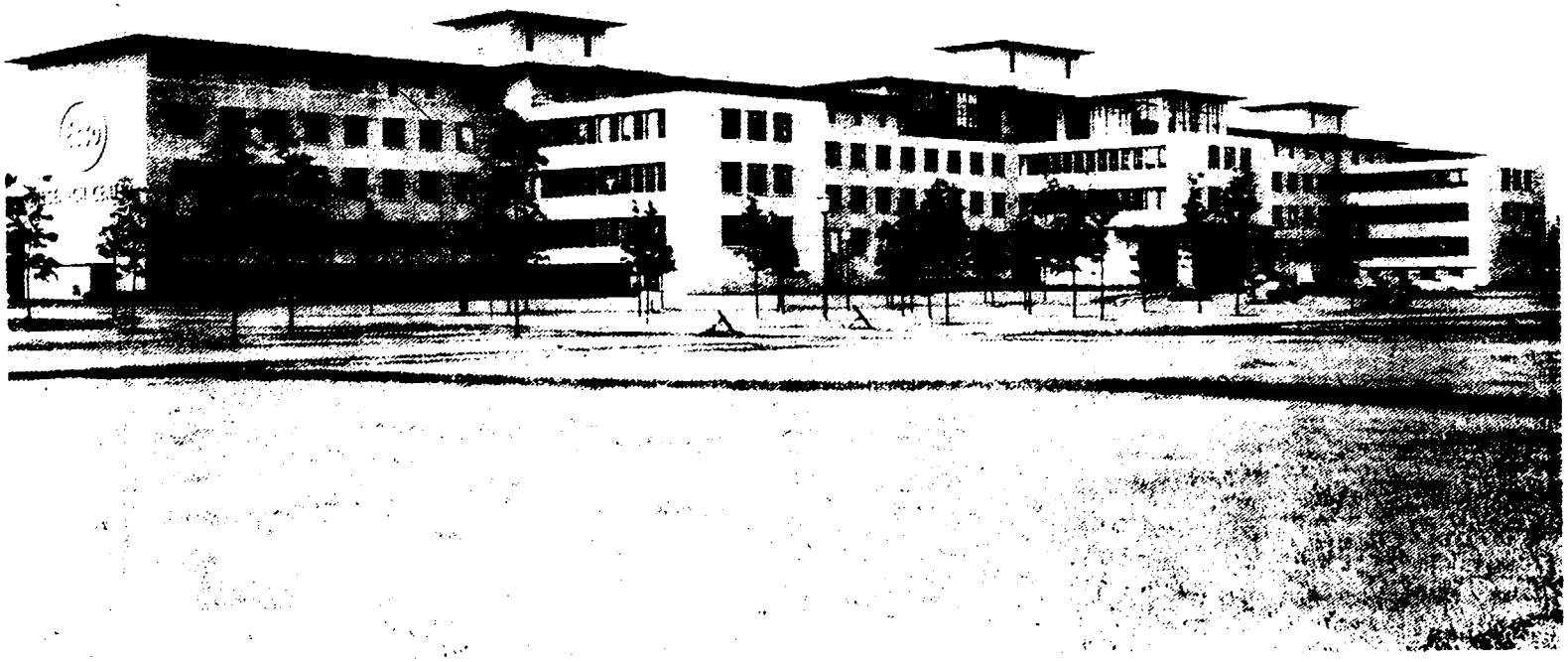

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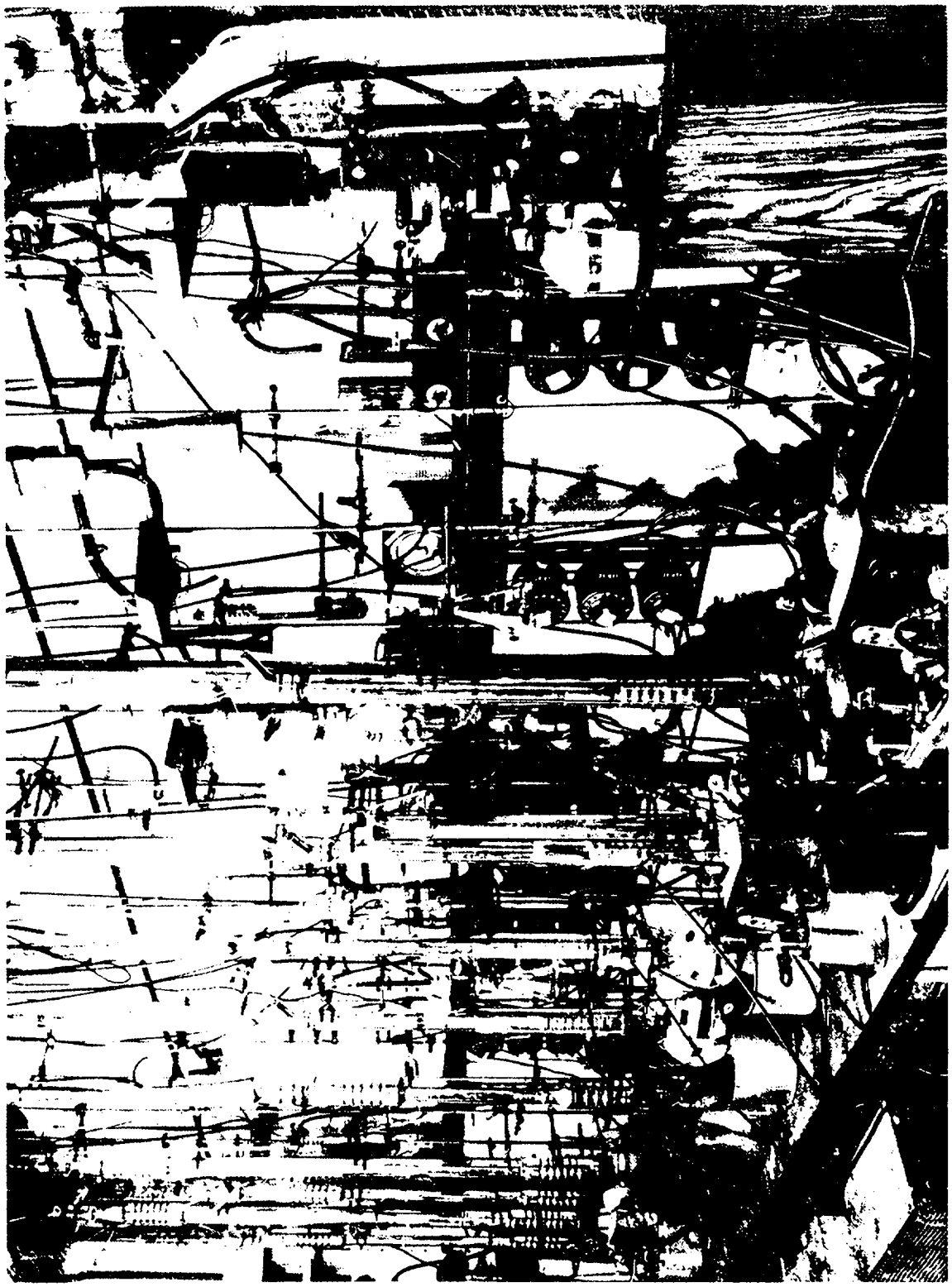
CHART 3



consumers' equipment in the field, but before this they are given exhaustive laboratory tests.

Chart 4, page 12.--This chart shows one of the test engines in our motor laboratory. This engine is fully instrumented so that we know exactly what it is doing and how the product is performing, and all that the man in the background has to do is write down what the instruments say.

In the same way, new processes have to be very carefully worked out and engineered before we can recommend that our affiliates spend many millions of dollars on a new plant. This is done in what we call pilot plants, and the next chart shows a typical large-scale pilot plant at our Baton Rouge laboratories.

Chart 5, page 13.--To give you some idea of scale, I might mention that this pilot plant is 11 stories high and must be equipped with an elevator so that operators and materials can get up and down quickly. It is in pilot plants such as these that we give the final tests to processes like Fluid Catalytic Cracking that are so important in the manufacture of aviation gasoline, synthetic rubber raw materials, and the like.

In addition to an organization plan and facilities, you also have to have people to do research. This is the most difficult problem of all, because modern industrial research is so complex and must concern itself with so many different problems that individuals acting by themselves cannot do it at all. If industrial research is to be effective, it must be carried out by teams of people in which various individuals bring specialized knowledge in a great many fields together for a coordinated attack on all phases of the problem confronting them. I would like to illustrate this by showing you another chart which is a simplified chart of our organization and by describing what was involved in the development of the Fluid Catalytic Cracking Process.

Chart 6, page 14.--This process was developed by the almost simultaneous efforts of people in six major divisions and, in general, during its development, a force of about 200 people were working on different phases of it. The Products Research Division had the responsibility for determining the types of products that we needed and

CHART 4

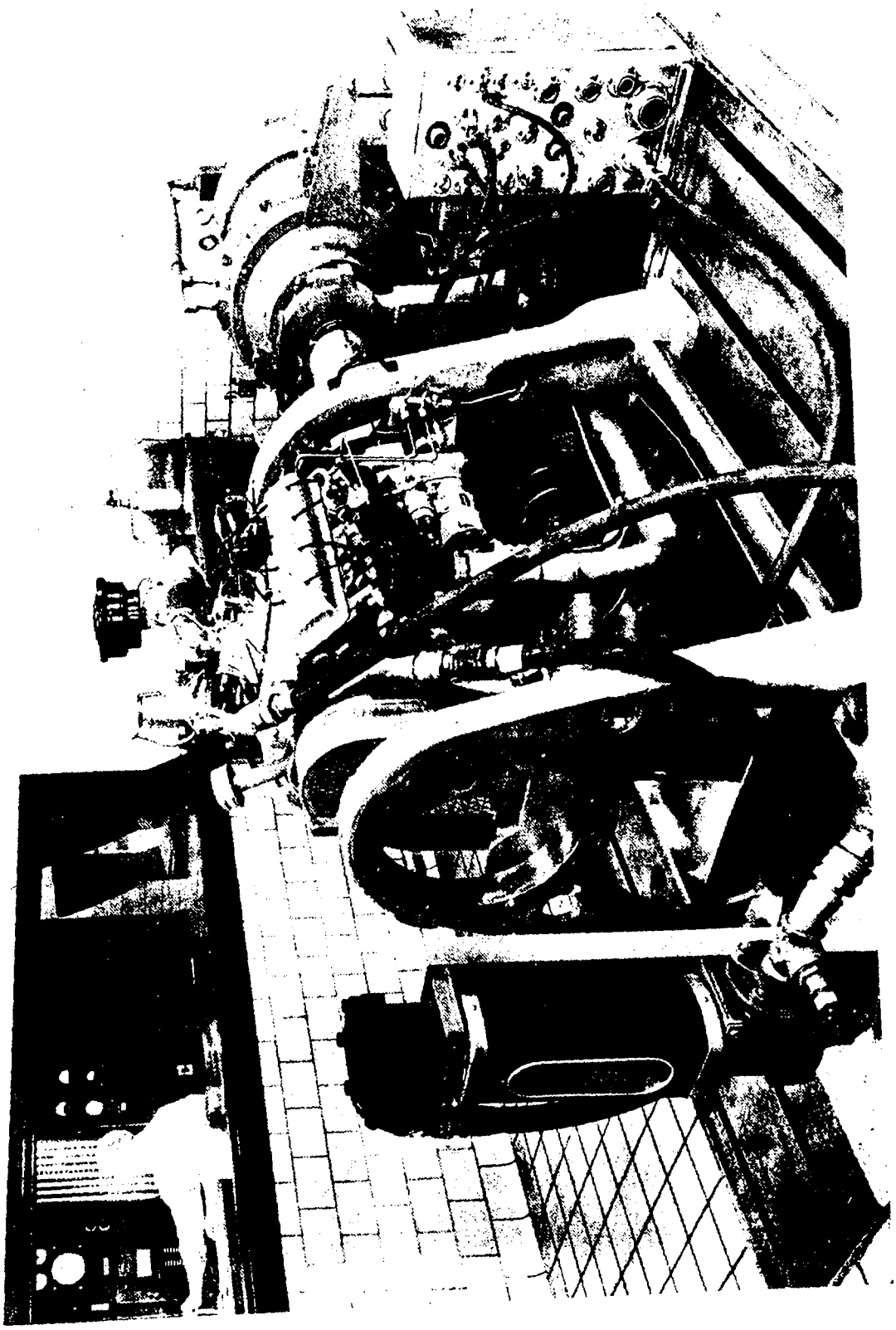


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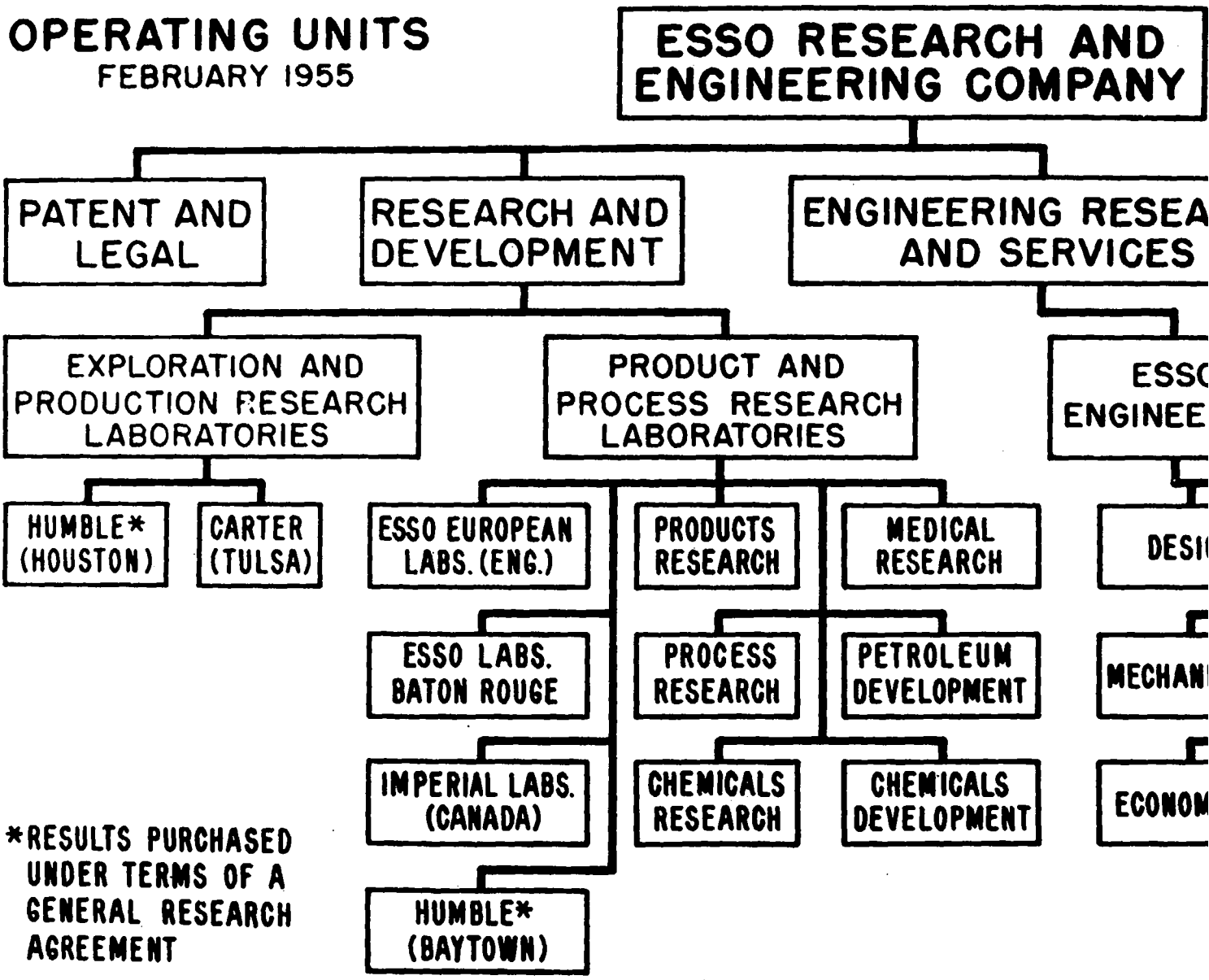
CHART 5

CHART 6


OPERATING UNITS
FEBRUARY 1955
ESSO RESEARCH AND ENGINEERING COMPANY
PATENT AND LEGAL
RESEARCH AND DEVELOPMENT
ENGINEERING RESEA AND SERVICES
EXPLORATION AND PRODUCTION RESEARCH LABORATORIES
PRODUCT AND PROCESS RESEARCH LABORATORIES
ESSO ENGINEE
HUMBLE* (HOUSTON)
CARTER (TULSA)
ESSO EUROPEAN LABS. (ENG.)
PRODUCTS RESEARCH
MEDICAL RESEARCH
DESI
ESSO LABS. BATON ROUGE
PROCESS RESEARCH
PETROLEUM DEVELOPMENT
MECHAN
IMPERIAL LABS. (CANADA)
CHEMICALS RESEARCH
CHEMICALS DEVELOPMENT
ECONOM
HUMBLE* (BAYTOWN)
*RESULTS PURCHASED UNDER TERMS OF A GENERAL RESEARCH AGREEMENT

for evaluating the experimental products developed during the course of the work. The fundamental research and basic development of the process was carried out in the Process Research Division, while the Baton Rouge laboratories developed the engineering information in their large-scale pilot plants. The laboratory and pilot plant work was closely followed by the Petroleum Development Division in an effort to steer the research along lines that would produce an economic process and at the same time give the engineering information required for large-scale plant designs.

All of this information was then fed into the Engineering Divisions, which had the responsibility of designing catalytic cracking units and working with the refineries on their construction and initial operation. At the same time, the Contract, Legal, and Patent Department was closely following the work to be sure that the process was adequately covered by patents and that we would be free to operate it without infringement of patents held by others. The people involved in this unified effort were organic, inorganic, and physical chemists, physicists, chemical and mechanical engineers, lawyers, laboratory analysts, pilot plant and engine operators, and specialized mechanics of all sorts. Not one of these individuals would have been able to do this job himself even were he to live for several hundred years, and I would like to emphasize again that in carrying out industrial research it is essential that we have the coordinated efforts of a carefully balanced team having the facilities and background to cope with all phases of these complex problems.

Another phase of modern industrial research that is important and that I think you should know about is concerned with its management. The management of industrial research has not only the responsibility of broadly meeting the objectives I have already mentioned--that is, finding out what needs to be done, getting it done, and seeing that it is used--but must also concern itself with the important internal problem of trying to decide just how much research its particular company really needs and how this effort should be distributed among particular problems. The basic thing to consider here is that research is only successful if it is useful and is definitely unsuccessful if processes and products that the company needs are not developed on time.

I think it is now clearly recognized that various industries and companies within an industry require a fairly definite research effort

if they are to be most effective. This effort, however, varies widely and depends upon the type of industry involved and the capacity of individual companies to utilize the results of research. In a given company it is easy enough, for example, to tell whether production is running ahead of sales or vice versa. Products either pile up in warehouses or the warehouses are empty and the salesmen are calling for products. The same sort of balance has to be achieved in carrying out research, and it is the responsibility of research management to sense when research is building up and not being used successfully or when a company really needs research and the results are not there. Another type of balance that must be achieved is that between various areas in which the company needs research, such as between raw materials, manufacturing operations and product development. Still another balance must be achieved between long-range and short-range research.

If a research organization concentrates all of its efforts on problems facing its company today, it will not have the answers that are going to be needed to solve the problems of tomorrow. If, on the other hand, a research organization concentrates on solving future problems, the company may not survive to take advantage of the long-range research results. The proper analysis of all of these various problems and a willingness to take calculated risks in deciding what should and should not be done is the real test of research management.

With this background on what an industrial research organization is like, I would like to illustrate the close relationship between the growth of an industry and its research and development by a few examples of how this works out. The oil industry, as with almost any other industry, is dependent on adequate raw-material reserves to keep going and from time to time almost everybody in the country has been concerned about the possible depletion of our oil reserves and the consequent failure of our industry to supply the liquid energy that is now so important a part of this country's strength in both peace and war.

It has been pointed out fairly recently, and quite often in the past, that we were on the verge of using up all of our raw materials, and figures have been cited showing the ratio of our reserves to annual consumption to prove this point. The basis for this is illustrated by the next chart.

Chart 7, page 18.--This chart plots the ratio of our proved reserves to consumption in the United States over the last 27 years. According to this chart, you can see that in 1927 we had less than a 12-year supply of oil left. This same situation existed in 1936 and again as recently as 1948. Actually, we have produced and sold many times the amount of oil indicated to be left to us when some of these earlier predictions were made, and there has been a great deal of confusion among the general public as to what was going on.

The difficulty is that the term "proved reserves" has a special meaning in the oil industry and is not at all what most people think it is. I might explain this by saying that all over the world there are many areas that we feel sure contain large quantities of oil beneath the surface. In portions of these areas we have actually drilled wells into the oil reservoirs and know that they exist. In still more limited areas, we have drilled enough holes to clearly define the extent and thickness of the oil reservoir. This is known as proving up a reserve and when the oil industry talks about its proved reserves, it is only talking about those reservoirs that have actually been measured and from which we are certain we can withdraw the calculated amounts of oil.

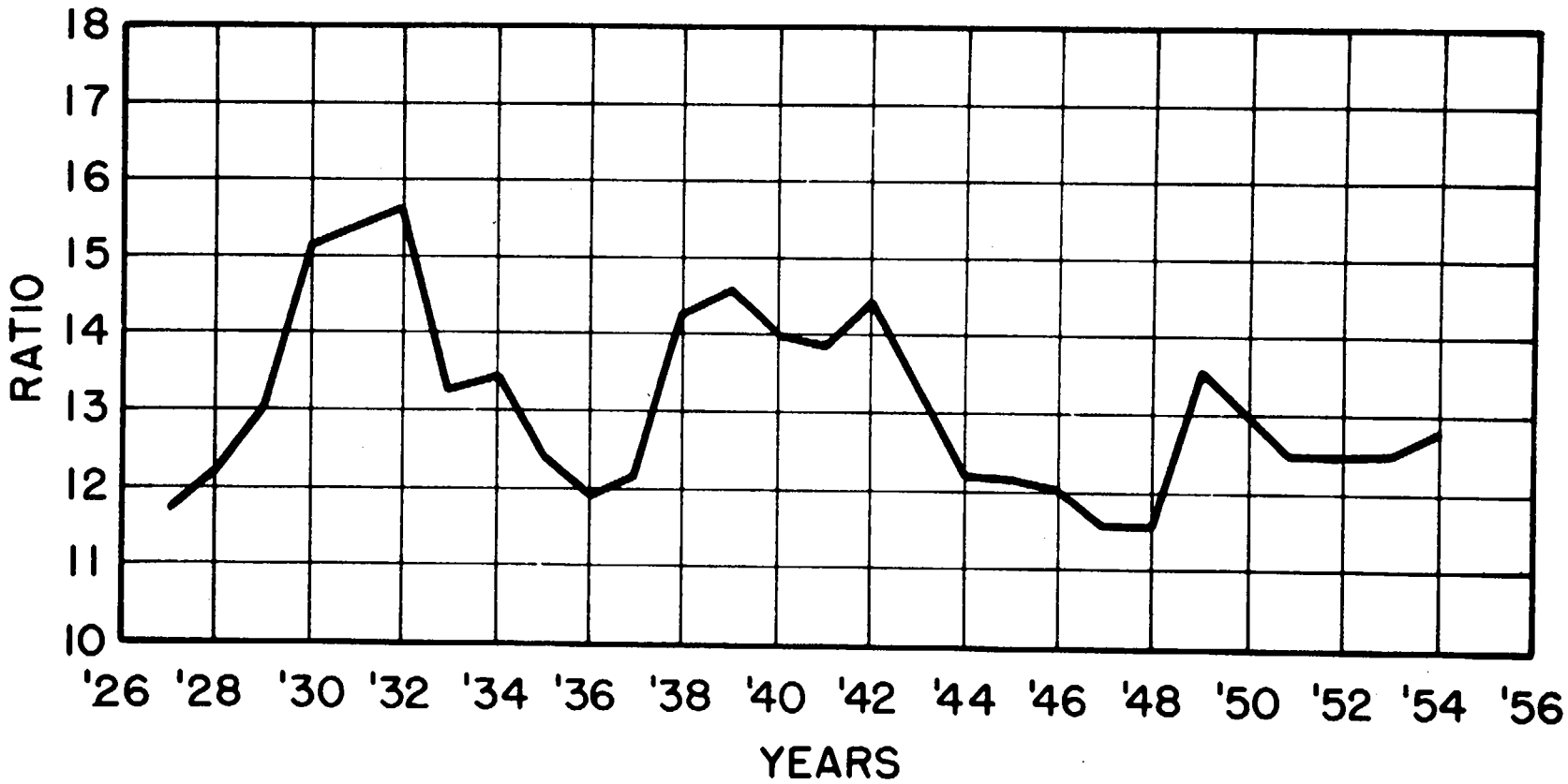
If you look at the chart, you will see that the ratio of these measured quantities of oil to production fluctuates around 13.1 in the United States. In order to understand these fluctuations, it must be realized that it costs a great deal of money to prove up a particular oil reservoir, so that a proved reserve represents a considerable capital investment.

From the standpoint of the petroleum industry, this is very similar to what in other industries are called working inventories of raw materials. Any industry, to operate efficiently, must determine its most desirable raw-material inventory. Obviously, if too low a raw-material inventory is maintained, there is considerable danger of temporarily running out of raw materials due to shipping difficulties, and the like. On the other hand, if too large an inventory is maintained, it ties up too much of the company's money and keeps it from doing other worthwhile things. Industries vary a great deal in how large an inventory is considered suitable. In some industries this might be as low as a 30-day supply, but in the oil industry in the United States, we have normally operated with about a 13-year raw-material inventory. When this gets below about that level, there is increased

CHART 7

RATIO OF PETROLEUM RESERVES TO CRUDE OIL PRODUCTION

1927-1954



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activity in proving up reserves and in locating new reservoirs. When the supply is much greater than this, the search for oil slacks off and the ratio starts downward as proved reserves are consumed.

Now I want to show you another chart.

Chart 8, page 20. --This shows the same information in a little bit different fashion. You can see here that, though we are taking more and more oil out of the ground each year, our proved reserves are steadily increasing. One of the reasons we have been able to do this has been because of a great deal of research in this field. Methods of locating oil are available today that represent a great improvement over the tools that were used by industry in its early days. Oil wells are deeper today than they used to be, but at the same time our techniques for drilling wells are improved and we have learned a great deal more about how to get more and more of the oil in a given reservoir up to the surface.

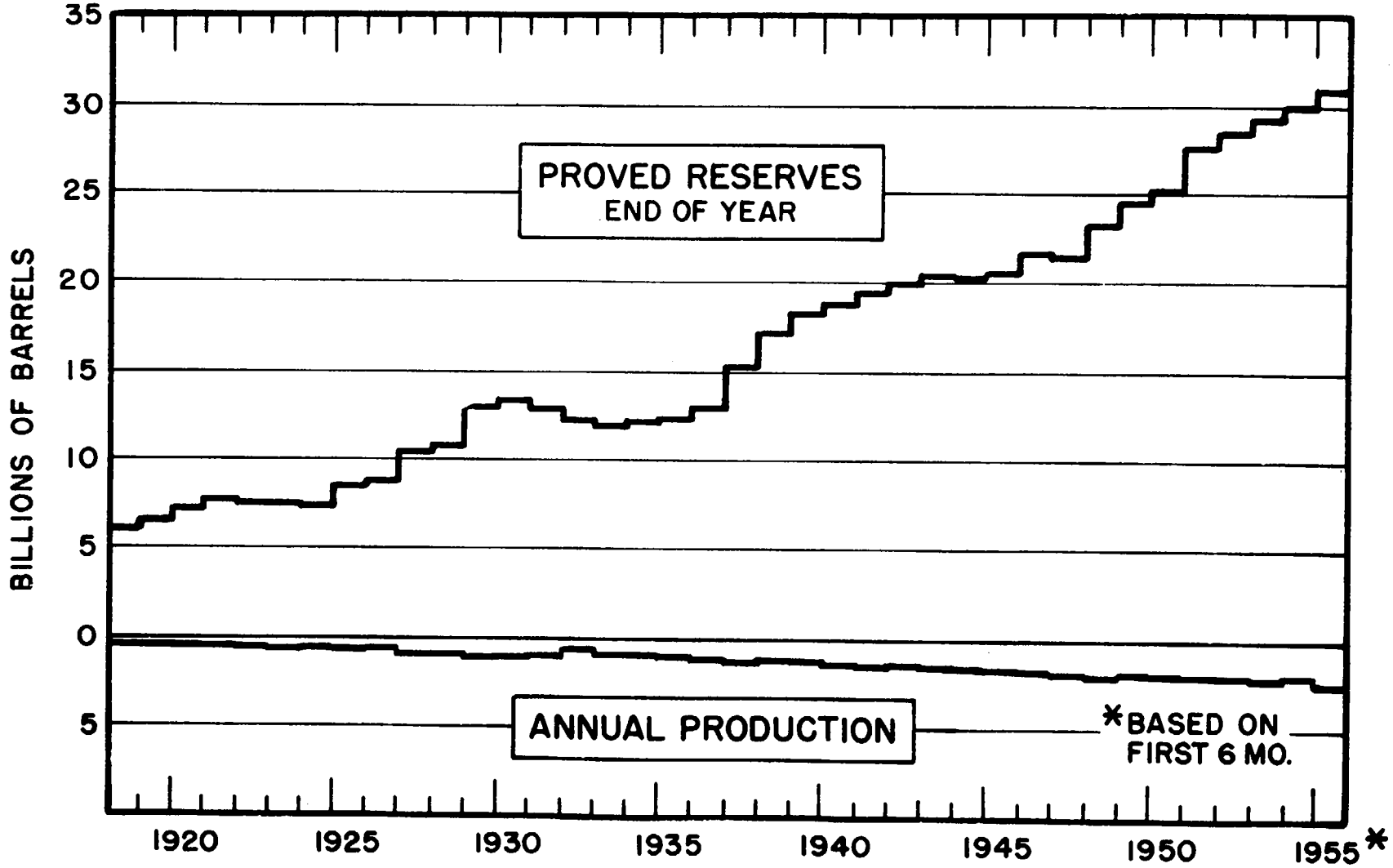
And so, as the search for oil goes on, it is each year more difficult to find, but also each year we have better methods of finding it, and in this way are able to keep in balance. In other words, research and development within the industry have compensated for the fact that we are using up our old reservoirs and have enabled the industry to find new ones about as readily today as in the past.

Another thing that the industry has done is to develop alternate sources of raw material. We regard ourselves as suppliers of liquid energy and would just as soon make the liquid energy from sea water if we could do it and at a reasonable cost. While sea water does not seem to be a very promising source of the kind of energy we are selling, there are in this country and throughout the world very large deposits of coal, oil shale, and tar sands that can be used in place of crude oil.

The industry has done a great deal of research and development on these alternate sources of raw materials and has technically developed processes which can make products from all of these fully equal in quality to those produced from crude oil. These processes are not being used right now because we have not been able to bring the costs down below that of our present operations. In some instances, however, it is getting quite close and if the industry had to swing over

CHART 8

UNITED STATES CRUDE OIL PRODUCTION COMPARED WITH PROVEN CRUDE RESERVES



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from crude oil to some of the other raw materials, this could be started tomorrow and the cost of gasoline, while higher than at present, would not be exorbitant.

The point I am trying to make here is that we are as much concerned as anyone else about our raw-material situation. We do not intend to go out of business because of it and have taken steps that will permit us to supply liquid energy from either petroleum or other raw materials for many, many years to come.

Another important phase of the industry's research is concerned with what might be termed the efficiency of its operations. The oil industry has, from the start, been extremely cost-conscious and has constantly carried out research and installed new equipment to reduce the costs of its products. As a result of all of this, gasoline today, ex taxes, is not much different in cost from what it was in 1925 or 1926 in spite of all of the inflation that has taken place since then. Furthermore, the quality of gasoline and other products is much better than in those earlier days. This quality improvement is very important, because through better quality gasoline more efficient engines can be developed, with the net result that about 50 percent more useful work is obtained from a gallon of gasoline today than was possible in 1925 or 1926.

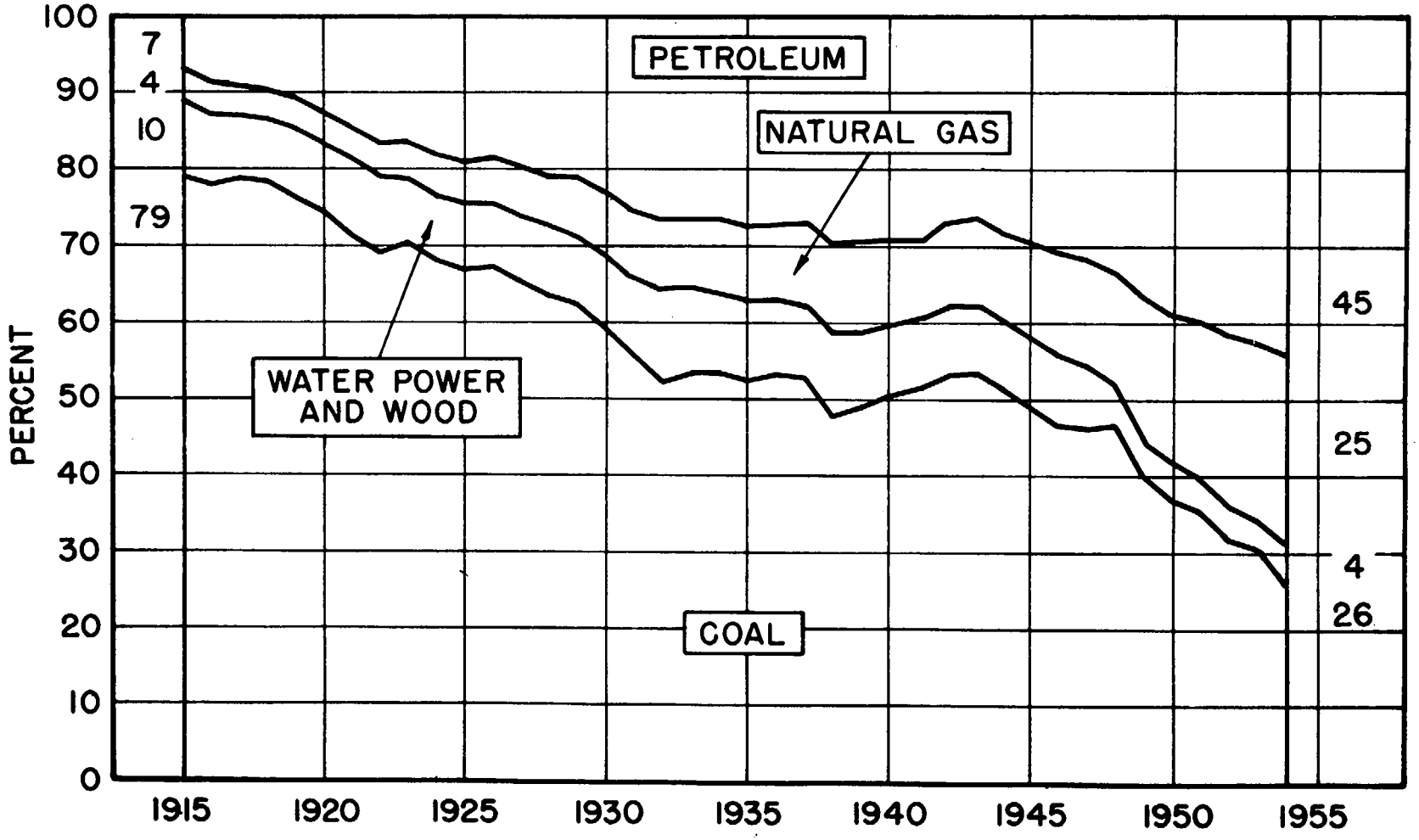
A classic example of how research along these lines can affect an industry is illustrated by the next chart.

Chart 9, page 22.--This shows the sources of energy in the United States since 1915. In 1915 almost four-fifths of the energy used was derived from coal. Today barely one-fourth is derived from coal, which is gradually giving way to petroleum and natural gas. It is interesting to reflect that during this period the oil industry has been carrying out an aggressive research program and has continually tried to keep its costs down and improve the quality of its products. This has not been done by the coal industry, with the result that it has not shared at all in the rapid development of our country as a consumer of mechanical energy.

A third interesting field of research has been concerned with products, and there are countless examples of how this work has led to new uses for our products and has helped the industry to grow. It was not too long ago, for example, that automobiles were put up on

CHART 9

U.S. CONSUMPTION OF ENERGY BY FUELS BY PERCENTAGE



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wooden blocks in the fall and left there until the spring. This was partly because the roads were no good in the wintertime and partly because people did not particularly want to go anywhere in the winter. It was also because the cars would not operate well in cold weather. With improved roads and the increased desire of people to drive around as much in the wintertime as in the summer, the oil and motor industries together have done a great deal of work directed toward making cars run just as well in the winter as in the summer.

For the oil industry, this has meant careful control of gasoline volatility and the development of new types of lubricating oils and greases, with the result that a new season has been created in which gasoline can be sold. We have also cooperated with the oil-burner manufacturers in the development of systems for household heating to the extent that today the sale of heating oil for this purpose is a very important part of our business. In the same way, we have worked with the manufacturers of diesel engines to supply just the right fuels and lubricants so that diesels can operate satisfactorily and now sell a great deal of liquid energy to railroads, which at one time operated entirely on coal.

In addition to what we call our normal petroleum business, the oil industry is actively entering a new field known as petrochemicals. In this field, organic chemicals, which can be derived from petroleum, are rapidly being made available, principally as raw material intermediates for the chemical industry. For example, the oil industry today produces large quantities of synthetic ethyl alcohol. Although technically this would be suitable for making alcoholic beverages, the synthetic alcohols are used for various industrial purposes and are converted into solvents, and the like.

We also manufacture large quantities of materials that go into the manufacture of plastics and supply some of the raw materials for the synthetic fibers such as nylon, dacron, etc. Synthetic rubber is another product of oil research. Practically all of the automobile tires used in this country have now joined gasoline and oil in being derived from petroleum. We now have hopes that plastic automobile bodies will likewise use petroleum products, and the day may come when the oil industry will not only supply the fuels and lubricants for your cars but will also supply most of the raw materials from which they are made.

In what I have said so far I have tried to emphasize the intimate relationship that exists today in industry between its operations and its technology. The technology of an industry is not just research people in laboratories; it is not an engineering staff in a separate building; but it is technically trained people throughout the organization and is as much as other operations a part of the industrial effort. Furthermore, the research and development of an industry are not provided solely by the formal technical knowledge of those associated with it. They are even more dependent on the knowledge and understanding on the part of the technical people of the problems of their particular company and their ability to work closely with each other as a team to meet problems as they arise.

When we come to the question of technology and national security, I am convinced that our greatest strength lies in the existence in this country of industries and organizations which have the flexibility and capacity to meet new challenges as they arise. During peacetime, no company or industry can insist that its competitors use techniques with which it is accustomed to dealing, nor do I think that in war we can depend on others to stand still or to fight according to rules that we might set up for them. This was dramatically demonstrated during the last war by the capacity of my own industry to produce synthetic rubber to replace natural rubber supplies that were unexpectedly lost to us and by its ability to create sources of aviation gasoline and all of the other petroleum products required by our fighting forces. This has also been true of many other industries, and I am certain that our future security will depend, as much as anything else, on the continued development in this country of industrial organizations which have the technological know-how and the capacity to react quickly when our security is challenged.

I would like to close by summarizing what seem to me the important points to remember as we think about research and development within industry and their bearing on our national security. Within recent years we have built up in this country an industrial capacity which derives its strength from continued research and development and technological know-how. Whereas in the not too distant past industry could survive by taking or leaving technical developments as it saw fit, today this is no longer the case. The rapidity with which industry has had to meet new challenges in both peace and war has given rise to a new relationship in which research and development extend throughout our entire industrial effort and are actually a part of it. This combination of business initiative and aggressive research

and development has brought about tremendous changes in our standard of living and capacity to produce even during the last 50 years. In this same capacity to produce and meet challenges resides our future security.

Thank you very much.

QUESTION: This budget you speak of in research and development, is that determined by the affiliate research center or does the parent company determine that, your Jersey Company?

MR. REEVES: You mean our budget?

QUESTION: Yes, your budget.

MR. REEVES: Well, we are, as I said, a separate company. We receive no money at all from the parent company for research. We have contracts with the various affiliates and each of those contracts are individual contracts, whereby they agree to support our research efforts in various fields to a certain amount each year.

Now the basis for the contracts varies, but I would say it is essentially as if we were in business for ourselves but restricted to the Jersey group for customers. Our ability to get good contracts with them depends on our ability to give them satisfaction from year to year. But the budgets themselves are set within our own company. They are an accumulation of the various research projects and they are largely determined by the number of people that we have. We have an overall budget which is set by our ideas of what our growth rate ought to be and then that money is distributed to the various projects on a sort of a merit basis.

QUESTION: You referred to the oil industry as the liquid-energy business or portable energy business. Can you tell us what you expect the relations of your industry will be with the atomic energy business?

MR. REEVES: Yes. We have been very much interested in atomic energy. We use it ourselves quite a bit. Of course, it's a very interesting research tool and it has been used as such for some time employing isotopes to tag chemicals and determine the course of chemical reactions and to study such things as wear in automobile engines. We use it in oil fields. We've put tracers into gas injected into an oil field to find out where it goes, which is very important to us. So, as a research tool, atomic energy is very important to us.

We also have an interest in it as an operating tool, to take the place of a catalyst, for example. We have a Van de Graaff accelerator at Houston that we are using to study high velocity electrons. We have a cobalt 60 source at Linden in a cave and that source is 1-1/2 times the activity of all the refined radium in the world. We are using it to study the effect of gamma radiation on various types of reactions. We are also studying neutron radiation, primarily at Brookhaven and a few other national laboratories. We think that atomic energy is going to provide us some day with a new tool to make better petroleum products.

In addition to that, I suppose what you have reference to is the question of atomic energy for the generation of electricity. There we are quite concerned in a way. We've been following it quite closely because obviously it's a potential competitor of ours. Our present view is that it is going to grow quite slowly and it will be many years before it does more than take up some of the additional energy requirements in the country.

Furthermore, we think that atomic energy commercial power-plant installations, at least for the next 15 or 20 years, are going to be in areas where other sources of energy are expensive, and those will tend to be the less highly developed areas. Now, that's good for us. We think that, if you can put atomic energy in an area that has a low standard of living and can get the standard of living up, people will then want to have roads and drive around in cars; they will want to keep their houses warm, and so on and so forth. So it's our general view that the atomic energy installations are going to increase our business rather than decrease it.

We have had that same experience before. You may be familiar with the fact that the oil industry is spending a lot of money in South America trying to raise the standard of living, and they are doing it through the International Basic Economy Corporation. We are doing it because we know that there is a direct relationship between the standard of living and the demand for petroleum products, and we feel that if we can get the standard of living up in South America, our markets will increase. It's a lot cheaper to develop new markets by getting the standard of living up than almost any other way.

I would say our overall view on atomic energy is that we think it's going to help us in research and it's going to help us in operations, and it's probably going to get us new business for many, many years.

QUESTION: Would you tell us something about your utilization of specialized groups to augment your research programs? I am thinking of universities and special companies that are experts or particular specialists in a phase of their overall technology. Could you give us an indication of how much of your research budget is spent in your house and how much is contracted out?

MR. REEVES: The last part is quite easy. I would say that only one or two percent is contracted out. That's because, we are a large group and we have developed specialists in various fields that are of particular interest to us. On the other hand, we do recognize that there are specialists who are much more adept in some fields than the people we have in our own organization. We make very liberal use of consultants. For example, we have some 40 or 50 consultants who are professors at various universities. We employ them on a continuing basis and use them as the need occurs.

We also do a certain amount of contract work. We have work carried out at Battelle, at Armour Institute, at Southwest Research Institute, and at other places, because in many cases they will have facilities that are available for research programs when we don't have the facilities, and in order to get going quickly and in order to do the work economically, we find it much more effective to contract it out. We are not at all proud about the matter. We think that if we can get it done cheaper by contracting it out, that's what we ought to do. On the other hand, we do find that, for the most part, an understanding of our own business is an important part of doing an effective research program, and that's what we don't usually find on the outside.

QUESTION: Presumably in your research you could have a breakthrough that would affect, say, the automobile industry where you would have a tremendous capital investment. My question is, if you are ahead of them or they are reluctant to adopt your development because it would entail a loss of capital investment or major conversion of their production process, just how is that worked out and how long, for instance, do you have to sit on a known improvement of a product so that the other industries will catch up?

MR. REEVES: I don't think that we have to sit on things very long at all. If you anticipate for example, that gasoline is going up in octane number from year to year, a breakthrough might be in the form of a process that would let you go to a much higher octane number with

better yields or at a lower cost. Now, since gasoline is made in a great many different units, what you can do easily is to start putting in the new process. When you have only a few units in operation, it makes only a small difference in the overall quality of the gasoline. But as you install new units each year, your quality continually goes up. What happens then is that, if the automobile industry recognizes the fact that we do have processes which are capable of carrying octane levels to a certain point, it lays its plans accordingly, too.

What usually happens in both industries is that breakthroughs do not result in radical changes in the product that the customer buys. They result more in a gradual change, even though there are radical changes in ways of making products which gradually replace the older processes. We wouldn't have the money ourselves to put in all new plants to make, say, a radically different gasoline because if we tried to do that in one year, we would be broke.

QUESTION: We hear a lot today about the shortage of engineers and scientists. I wondered if the oil industry is being affected in its research and development activities by the inability actually to obtain people with proper background education and experience? Do you think this is really suppressing advancement or do you think, as some people contend, we are setting our sights too high and demanding too much experience from our people, that we could do with lower qualified levels of individuals?

MR. REEVES: Yes, I appreciate there is a shortage. I haven't been as concerned about it as a lot of other people have. In the first place, the shortage is mostly where a new discipline grows quickly, such as in electronics. There is quite a shortage in the electronics field, but that's mostly because there has been so much activity and growth in that particular field. Primarily, it seems to me, that as far as the oil industry is concerned, our growth is determined by our own ability to use new technology. In other words, we think that we can expand our technical effort by five or ten percent a year, and that's what we are trying to do.

Now it has been our general experience that people certainly are graduating, and if you go about it properly, you can get them. What has happened to us, though, is that it involves a more intensified recruiting effort over what we used to have to use, and from the standpoint that we have to take time out to recruit, obviously, we are not doing the other things that we want to do. But so far we have found

that we have been able to employ the people that we have budgeted. It's our attitude that, if we need, say, 300 people, as we do this year, and more than 300 of the kind we are after are graduating, we will let somebody else worry about the shortage. It's our feeling that if you know what the problem is and go about it properly, you can solve it. Somebody is going to get stuck with this deal, but the people who are going to get stuck are the ones who don't realize what the problem is.

All in all, I would say that, while there is undoubtedly a shortage of technical graduates today, the situation is greatly magnified by spot shortages in selected disciplines and that overall the situation should be described as tight rather than serious.

QUESTION: Sir, we read where other companies spend three or four percent on research. I appreciate the fact that you have a separate organization from Standard of New Jersey, but could you give us some idea of actually what you are spending in research compared with some of the other leading oil companies?

MR. REEVES: We are spending around seven or eight tenths of a percent. I would say that we are about in the middle of the thing. Shell, for example, spends a higher percentage than we do; most of the others spend a little bit less.

I think the thing you must remember when you talk about percentages of sales is that sales don't really represent the need of a company for research. Take, let's say, a Supermarket, for example. Their turnover is tremendous. They couldn't afford a large research effort expressed as percent on sales because the need for research is more connected with the value added by manufacture, which is very low in their case. If you express research people as percentage of total personnel or value added by manufacture, you probably have a much better relationship for indicating the need of an industry for research work.

A lot of our sales are involved in buying and selling crude oil, and to that extent, I suppose our sales don't represent the same thing as the sales of the chemical industry. I have tried to make comparisons on the basis of value added by manufacture; and the oil industry, the chemical industry, and most of the others are very close on that basis. I think that the percentage of sales figure is all right if you are comparing companies within an industry which are doing about the same kind of thing, but if you try to use it to compare from one industry to another,

you get an idea from those comparisons that some industries are doing a lot more research than others, and it may be almost reversed when you get right down to it.

QUESTION: I wonder if you would go back and elaborate a little bit on the remark you made concerning your projects arrangement when you showed the simplified organization chart. I am wondering first how you would administer the project as opposed to your regular organization line and then perhaps what the duration of the individual personnel assignments to these would be?

MR. REEVES: Okay. As you may remember, we have a number of operating divisions. Now those operating divisions sometimes do different types of work or sometimes they are just separated geographically. For example, the affiliated Baton Rouge Esso Research laboratories normally do most of our large pilot plant work. The various development divisions do only special engineering work. They do chemical engineering and economic studies. Our engineering divisions are primarily in commercial plant-design work, and the Products Research division works on products, and so forth.

When we have a new project that requires a lot of different backgrounds, such as a study of product performance, a study of the process development, and things of that sort, we have to get all of those different groups pulling together on the project. We do it this way:

We are divided into what we call major areas of research, such as fuels processes, products, chemicals, and so forth, each of those in charge of a vice president of our company who has with him a deputy coordinator. The vice president is both administrative head of certain of the divisions and the coordinator of the work in a particular field, and it is his responsibility then to coordinate the programs, either personally or by assignment to others in the various development divisions.

It's not as tough as it may seem because all of our budgets are program budgets, and the coordinator of fuels processes, you might say, has a blank check for maybe 12 million dollars to do his work on fuels processes. Our program budgets add up in toto to the individual budgets of the divisions. It works out pretty easily because, if the division doesn't do work for one of the coordinators, it doesn't have enough authority to spend the money it's supposed to spend.

I could put it this way: What we have is a whole series of divisions which are responsible for carrying out a different type of technical activity, and they are actually the working groups for the coordinators who control the type of work done in the various fields. In spite of its complications, it works out very well.

QUESTION: I gathered from most of your remarks that the research of your company is in the line of applied research with a somewhat definite objective. Some speakers are very much worried because of the small amount of funds available for pure research. Does your company contribute to any pure research agencies or do you allow any of that type of research in your company--in other words, a scientist off by himself with a free hand to come up with whatever he can find?

MR. REEVES: That's an interesting question. I would like to answer it in a number of ways. In the first place, we do sponsor a certain amount of what might be called pure research at universities, but I think you have to consider that when you attack any problem, whether it is an applied problem of immediate importance or a long-range problem, you ought to be scientific in your approach to it, and you ought to make basic studies.

For example, if we were concerned about developing an isomerization process to make higher quality naphthas or even in improving the present process, we could easily get ourselves into a study of the thermodynamic properties of the individual isomers involved because we would need those data to calculate the thermodynamic equilibria and the octane number of the equilibrium mixtures, to develop suitable processes for isomerization.

That, I would say, is fundamental work of a very high order and if it were done by somebody who didn't have any particular reason for doing it, it would be called basic research.

The point I am trying to make here is that I think there has been a lot of misunderstanding. I think most industrial research organizations try to be scientific in their approach to all of their problems, and I think a great deal of scientific work of a very high order goes on all the time in industrial research organizations, whether it is called applied or what have you.

What we are concerned about is what we call long-range research. In other words, we are interested in a group that will do research on research. I might explain it this way: We think that our relationship to the operating company is that we take a longer range point of view than they do concerning their problems, and we tend to be much more concerned with what they are going to have to do next year. They don't care so much about that as long as they get through this year. So what I think our industrial research organization needs is a group that will look even further ahead and make more studies of the kinds of things we might be able to do in fields that would be of interest to the company in the more distant future. We support a fair amount of work of that sort and it amounts to about 10 percent of our technical effort. I would say that the average for industrial research generally is somewhere between five and ten percent. Now that's pretty high when you consider that research itself is only one or two percent of the total industry. I think this is a very interesting question and a lot of people who have been talking about this business of uncommitted research are just talking about the fact that they don't want anybody to tell them what to do. It is not a question of the type of work that's being done or the objectives. It is simply that they just don't want to be told what to do.

QUESTION: My question has to do with the way in which you advance your technical personnel in your research and development organization. Do they go into administration so you have a dual line for scientists? I am wondering whether a man can be purely technical and move up to the top executive salary scale or must he become an administrator and take on administrative responsibility?

MR. REEVES: We do have two methods of advancement. We have titles known as Senior Research Associate and Senior Engineering Associate, and those titles we consider equivalent to an Assistant Director and Associate Director in one of our major divisions. I think it is fairly obvious that you can't expect a person who wants to go along purely technical lines, say, to reach the responsibility level of the president of the company.

We have in our company, I would say, about 2 percent of our technical people at a salary level above what we would expect an individual researcher to reach. But we do, other than in that top 2 percent, try to make certain that, if someone wants to spend his time making technical contributions to our organization, he is adequately

rewarded for it because we are a technical organization and technical contributions are what we need. Therefore, we try to see that those who want to advance as scientists are given the opportunity to do so and that those who want to follow more administrative lines of progress can do that, too. We have always taken the position that, for a given ability, we are going to give equal recognition in terms of salary and privileges, and what have you, based on the contributions of the individual, whether it be scientific work alone or whether it be administrative work.

QUESTION: I am curious as to the percentage of energy that you are able to get out of your drop of petroleum or crude oil now and also what the future holds, how much are you going to be able to get?

MR. REEVES: Well, if you are just talking about combustion energy it depends on how it is used. If you use oil for household heating, for example, you will probably recover about 85 percent; if you use it in an automobile, you will probably recover nearer 10 percent. If you use it in a diesel engine, operating under steady load conditions, it may be 25 percent; on a truck it may drop down to 20 percent because you don't get the same efficiency. I suppose if you add it all up, we are recovering today about a third of the energy in petroleum. Most of what is lost goes out as unrecovered heat.

That, of course, creates a problem for us because the automobile industry, for example, is getting active technically and here we sit supplying them with the type of products they say they need today and are going to need in the future. We are installing plants today which will have to run 10 or 15 years if we are going to get our money back, and yet we are faced with the fact that what we are doing is supplying fuel for engines that are only 10 or 15 percent efficient. It seems fairly obvious to us that sometime the automobile industry is going to figure out how to do it better, and that, if it gets an engine that is quite different in efficiency, it is probably going to be an engine that is quite different in fuel requirements. it could be that the plants we install today are not going to be any good to us in five or ten years. So it is a very important thing to us to understand the efficiency with which our products are used and what the possibilities are for the future.

I would say that some day you are probably going to get fuel efficiency of 50 or 60 percent rather than the percentage we have today. But I do think you have to remember another thing. It is all right to

talk about conservation of natural resources. On the other hand, what we are living in today is what you might call a luxury economy, and if you want to worry only about conserving resources, you ought to go back to a 30 or 40 horsepower engine instead of a 300 horsepower engine because that's all you really need to move around. What people are doing today is using the resources of the country the way they feel like using them. We feel, as far as our own business is concerned, we can keep on supplying people with energy just as long as they want to pay for it. We don't think that the fact that they are wasting it, so to speak, either by having low efficiencies or by using higher powered cars than they need, means they are going to run themselves out of raw materials. We just don't think that's so.

QUESTION: I wonder if I can relate some things and some that might have more direct application to the military. In your research, do you attempt to assess or gage what might be the future type of transportation systems, using, say, liquid energy?

MR. REEVES: Yes. Is that enough of an answer for you?

QUESTION: Yes, sir, it is.

MR. REEVES: I think I know what you are getting at. I think that it is most important that the research groups have a clear understanding of what the future requirements are going to be for weapons systems or transportation systems, or what have you, because you can't carry out an effective research program unless you have some idea of what you are trying to wind up with.

MR. HENKEL: Mr. Reeves, you have given us some very valuable information. On behalf of the College, I want to thank you for making it so interesting and instructive.

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