TECHNOLOGICAL PROGRESS WITHIN INDUSTRY

13 October 1953

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Mr. E. Duer Reeves, Executive Vice President, Standard Oil Development Company, was born in New York City in 1909. He was graduated from Williams College in 1930 with a B.A. degree and did graduate work at Princeton University. He left Princeton in 1931 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 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 Standard Oil Development Company in New York City and has been with the company as Executive Vice President since January 1949. Mr. Reeves is a member of the following organizations: The Society of Automotive Engineers, American Petroleum Institute, American Chemical Society, Directors of Industrial Research, Industrial Research Institute, Society of Chemical Industry, Armed Forces Chemical Association, Advisory Committee for Conference on the Administration of Research, National Association of Manufacturers; Advisory Council, Department of Chemical Engineering, Princeton; Advisory Committee of Research Division, New York University; Office of Defense Mobilization Committee on Specialized Personnel, Phi Beta Kappa, and Phi Delta Theta. This is his first lecture at the Industrial College of the Armed Forces.

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CAPTAIN SWAIN: Good morning, gentlemen. Part of the scope on which our course is based reads: "A study of the relationship between technological progress and the mobilization of the national economy." That is a pretty broad subject. The industrial part of that subject is one of the most important facets. Our speaker this morning, Mr. E. D. Reeves, is indeed well qualified to speak on it.

As Executive Vice President of the Standard Oil Development Company, he knows thoroughly industry's part in research and development, as well as the impact of technological progress on industry itself. I feel that no one could give us an insight into the subject of technological progress within industry better than can Mr. E. D. Reeves.

It is a pleasure, sir, to welcome you to this platform.

MR. REEVES: Thank you very much, Captain Swain.

Good morning, gentlemen. I would like to start off by saying that I am certainly very happy to be here today and have a chance to talk to you about something that is very dear to my heart. Ever since I got out of school about 23 years ago, I have been involved in industrial research. It has been a very interesting subject and it has been very interesting to watch it grow. I would like to tell you this morning a little bit about how technology ties in with our overall industrial effort.

The first thing that I think we ought to recognize about our industry's technology is that technology is not a thing apart. It is not carried on simply in the hope that something good will come of it, but is carried on as a truly integral part of the overall industrial effort.

When I first started to do research work in 1930, the United States was spending about 160 million dollars a year on industrial research. Today the bill for industrial research is approximately 2.4 billion dollars a year, which is a fifteenfold expansion in just the last couple of decades. From that I think you can see how fast industrial research has grown and how it now spreads all through our entire industrial effort.

I am in the liquid energy business; I represent a business which believes in research and has grown through a combination

of business initiative and an aggressive industrial research and development program. It is a growing industry and illustrates very well, I think, the interdependence of technology and industry today. On the other hand you should realize that my industry is an average industry. There are many other industries in this country that place less dependence on research and development work than we do. There are also many industries that place more dependence on industrial research than we do, such as the pharmaceutical industry, the chemical industry, and the electronics industry. So that generally speaking we are an average American industry. I think that as I talk about the energy business today, you should realize that what I am talking about is a typical relationship between technology and industry that pervades the entire structure of the American industrial effort.

As we talk about the broad subject of technology in industry, there are a lot of things we can discuss; but I think we should concentrate on four items this morning. The first thing I would like to talk about is what industrial research really is and how the energy business has grown through it. Then I would like to go a little bit into how we go about organizing and managing industrial research. The third item I think we should cover is concerned with the kinds of things that can be accomplished and have been accomplished through industrial research in this country. The final thing I would like to talk about for a few minutes is what I think all of this means in terms of our national security.

Coming back to the first subject, "What Industrial Research Is," I would like to emphasize again that it is not the glamorous business that a lot of people seem to think it is. It is not something that is carried on in a corner. It is not so much something that is carried on by people in white coats. It is a part of our industrial effort. It is carried on by American industry in an effort to improve its competitive position. It is a part of the whole business, just as much as manufacturing, purchasing, and sales are. In other words it is a part of the coordinated team effort.

As such it has very definite objectives and responsibilities. It has a great many responsibilities to the people who support it. One of these, and an important one, is to find out just what a company needs in terms of research and development and technology. This means going to the company's customers, and potential customers, and finding out what kinds of things they do, what their needs are going to be in the way of new products, and what kinds of products would suit their purposes best. For example, in the case of the automobile industry it is our responsibility to go to its representatives and try to find out what their plans are for the future, so that we can provide the people who buy automobiles with the kinds of products they need and are going to want.

The raw material situation is very important. You have to be sure of the company's supply of raw materials. You have to be sure that the raw materials that you are using represent the lowest-cost raw materials available to your industry.

So I think one of the first things that a research organization needs to do is to know its company extremely well, maybe almost better than some of the operating executives. It has to know definitely just what that company needs in the way of research and development work.

After all of 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.

A third objective and responsibility of the industrial research organization today is one that is not always recognized. It is the responsibility of seeing that the results that are produced are actually used. It does no good to develop a new product or a new process, if the new products are not manufactured and sold or the new process is not installed. We have to follow these things through. First, we have to produce things that we think are needed, and then we have to do everything we possibly can to bring them into use and help other divisions of the business to put the results of the research to work.

The key to all of this, of course, involves participation by the industrial research people in the business activities of the company. Those in charge of research have to participate in the major policy decisions that their company makes. Technology in industry today is more of a point of view than anything else. When a business tries to decide what to do in the future, its board of directors and its executive committee have to have available to them the point of view of those who are familiar with technology. Today business decisions are based as much on the technological, the research and development, point of view as they are on business outlook, the raw materials situation, or anything else. So that is a main consideration--you can't separate industrial technology from the industry itself.

When it is carried out this way, industrial research can really be a very powerful tool for industrial progress. The energy business is a striking example of how this can be accomplished, and how the results of proper teamwork between technology and industry

can be an influence for good for all of us and can really affect our whole way of living.

I would like to go into the energy business itself a little bit. I would like to emphasize some of the things that I suppose you all know but perhaps don't think about so much.

In the first place, the energy business itself is a new business. It was born in 1760 when James Watt invented the steam engine. That was not very long ago. It was, as you know, about the same time that the Government of the United States was being formed. When you consider all the years that man has been on this earth, it is as if you woke up one morning and suddenly found something had happened overnight that would materially alter your entire way of life.

But after this invention in 1760, the energy business was to go through a long period of incubation, which almost ran into the 1900's. During this period steam locomotives were built, some houses were heated with natural gas and people were just beginning to learn something about the potentialities of this new mechanical servant that had really been brought to life by James Watt's invention of the steam engine.

The slowness of the rate of growth of the energy business is illustrated very well by the almost incredible fact that in 1814 only 22 tons of anthracite coal were mined in the United States. That is about enough coal to heat a good-sized house through the winter. Even by 1820 there were only 300 tons of bituminous coal mined in the United States. That is about enough to keep the War College warm through one winter. So you can see that as late as that there was very little mechanical energy being produced in this country.

It wasn't until about 1850 that the fossil fuels, such as coal, began to have much impact on American industry. By 1850 over 2 million tons of coal were being mined each year and converted into energy. The year 1859 marks the beginning of the liquid energy business in this country. That was the year that the Drake discovery of a well in Pennsylvania started the oil industry.

During the period 1850 to 1900 people were beginning to realize more and more the tremendous potentialities of mechanical energy for raising their standard of living. They were beginning to appreciate the fact that a lot could be done by substituting steam for horses and their own backs. But even that period pales into insignificance when you think about what has happened since.

Since 1900 we have consumed in this country over 85 percent of the total fossil energy that has been consumed in the world since time began. In other words, we have used in this country, almost in our own lifetime, six times as much energy as all of our ancestors were able to get from fossil fuels and other forms of energy, such as waterfalls and the like.

So you can see that what we are talking about is something that really is new. It is hard to realize, accustomed as we are to central heating, automobiles, electric lights, and power plants, that what we are talking about is in reality the story of an amazing turn of events that have taken place only within the last 50 or 60 years. It is something that was not available to some of our immediate ancestors.

I would like to give you some more illustrations of how rapidly this change has been taking place. In 1850 only 6 percent of the total work performed in this country came from mechanical energy. By 1900 it had grown to 38 percent--still less than half. Today 95 precent, or 20 times as much as we get from our own efforts and from horses, is produced by mechanical energy. This is from coal, gas, and oil, with some assist from wood and waterpower, which is today a very small part of our total energy picture.

So I think when you add it all up, you come up with the fact that during the last 50 or 60 years we have built up a new kind of economy in this country that is based on the use of mechanical energy, derived from coal, oil, and gas. This mechanical energy, coupled with the machines that utilize it, has given to the people in our country added work equivalent to about 200 mechanical slaves. In other words the addition to our working capacity that is available to us because of the use of mechanical energy is about 200 times our total population.

That is important for a lot of reasons. It is of interest to note that in 1850 almost two-thirds of our total working population were on farms and their work was required just to supply the rest of the people with enough food to keep going. Today less than 15 percent of our population is required to feed the country.

Our standard of living and way of life is something that was not matched even by the greatest of the civilizations of the past. Everybody in this country today, because of the industrial developments that have taken place, has really the equivalent of about 200 slaves or servants working for him. You can readily see how this gives people an opportunity to do things today that they did not have even 50 years ago.

I am not claiming everything that has happened over the last 50 years for the energy business. Nor am I claiming everything for its research and development effort. I am sure it is perfectly obvious to you that the people concerned with the development of the energy business did not also invent the automobile or develop the automobiles, the steamships, and the airplanes and all of the pieces of equipment that use energy in this country. They also did not invent all the appliances and products that are pouring from our factories, such as refrigerators, washing machines, and so forth. But I do think that energy is the key stone to all of this; and that if it had not been for the development of mechanical energy, and the development of sources of mechanical energy, we would not have the standard of living in this country that we do have today.

I will get back to the energy business, particularly the liquid energy business, which is probably the most vigorous phase of the energy pciture. This is what we call the petroleum business. It produces gasoline used in automobiles and airplanes, the diesel fuels used by railroads, trucks, and steamships, and the residual fuels that are used by our power plants.

This business has grown up through research. I think it is quite characteristic of what happens when you can get a successful blending of an aggressive research and development program with business initiative.

It has been a very independent industry in many ways. The people in it have had to go out and scratch for themselves and build up the industry in the face of a lot of opposition until now it is an effective industrial concern. It is one that does believe in research. It is an average American industry. So I think you can get a picture here of what business initiative has been able to do in this country, and what technology in general has been able to do, as it works with industry, and how technology is tied up to our way of life in this country.

When you talk about the technology of the oil industry, I think you have to recognize that the oil industry or the liquid energy business is a very complex business. It involves an unceasing search for crude oil all over the world. You find oil in the United States, Canada, the Arctics, South America, the Middle East, Africa, and Alaska. It occurs all over the world. Once you find oil, you have to figure out how te get it out of the ground and how to transport it to the refining centers. It wouldn't pay to develop a crude oil source if you couldn't get it to where you could refine it. Then the fuels have to be transported to the individual distributing centers, like the service stations. Finally it has to get to the customers. There are also a great many things involved besides just finding the oil and getting it distributed.

As new machines are developed, the liquid energy business has to develop new products of its own so the new machines can use the fuel most effectively.

All of our machines depend on lubrication to operate efficiently. Friction is the great enemy of almost all machines. It has been necessary for us to develop a great variety of special lubricants and greases to permit our machines to operate without losing most of their energy through friction.

Also the oil industry has entered a new phase recently, in which the compounds now being used for energy can also be used to make chemicals, plastics, synthetic rubber, solvents, and other specialty products. All sorts of chemicals are being made available to us on a much broader scale through the use of petroleum products.

This is the field in which we do research and development work. I think that when you realize that research and development work itself is not simple, you can see that the problem of coordinating it, and also coordinating technological activities with operating activities, is really a complex one.

The research and development organization has to do a lot of different things. It has to meet the objectives that I have just outlined, for finding out what is needed, getting the work out, and getting the results used. It has to deal with very many individual problems. It has to carry out work of many different types. It has to carry out fundamental research work. It has to study the exact properties of matter, and it has to do applied research on the results of the fundamental work.

The principles that we discover in our fundamental research have to be translated through applied research into new processes and new products, and these have to be put into use. There are things like patents and other legal matters that may have to be gone into. Our industrial research covers a very wide field. It also has to deal with the complex problems of an industry. So I think that a proper organization for carrying on research and development in an industry like this is really a key factor in determining its success.

I think the best way I can illustrate this is to tell you a little about my own company. I am doing this not only because I know more about it than any other company; but also because in many ways it is typical of the problems that are faced in trying to carry out a coordinated research and development effort.

Chart 1, page 9, Organization chart of the Standard Oil Development Co. This chart will illustrate the fact that an industrial research organization is a very complex organization.

In my company our industrial research is carried on by a separate organization, called the Standard Oil Development Company. You can see on this chart that we have divided ourself into four main fields of activity. One is our research work; a second, development work; the third, engineering; and the fourth is contract, legal, and patent work.

This organization chart covers the activities of about 3,000 men and women. We have numerous laboratories to carry out the research and development work. These are located in a number of different places. There is one in each of the following places: Linden, New Jersey; Baton Rouge, Louisiana; Houston and Baytown, Texas; Tulsa, Oklahoma; Sarnia, Canada; and London England. We have put them in different places because all over the world we run into different problems, and we like to do some of our research and development where the problems arise. We find that it is a lot more effective.

I would also like to call your attention to the fact that in addition to the research and development groups, we have quite a few nontechnical groups. We have our own medical department, accounting office, and public relations office; and we maintain our own library and patent department. So in general a research and development group today carries out all of the business activities of a normal business.

Chart 2, page 10, Research Center, Linden, N. J. Another thing we must have for research and development work is technical facilities. This chart shows our research center at Linden, New Jersey. This building houses about 600 people. It is fully equipped with everything required to do an effective job of research and development.

Chart 3, page 11, Portion of a Testing Laboratory. This chart shows a section of one of the laboratories that we use for testing. This happens to be a solvent extractive system useful for making aromatics that go into TNT.

Chart 4, page 12, Test Engine in Motor Laboratory. Before our products are evaluated in our consumers' equipment in the field, they are given exhaustive laboratory tests. This is very important. We have to be very careful to see to it that the products we put into the field will really do what we say they will, and that they will be of benefit to the people who use them. All these products must be very extensively fieldtested. But, even before they are fieldtested, they have to be tested fully in the laboratory

CHART 1

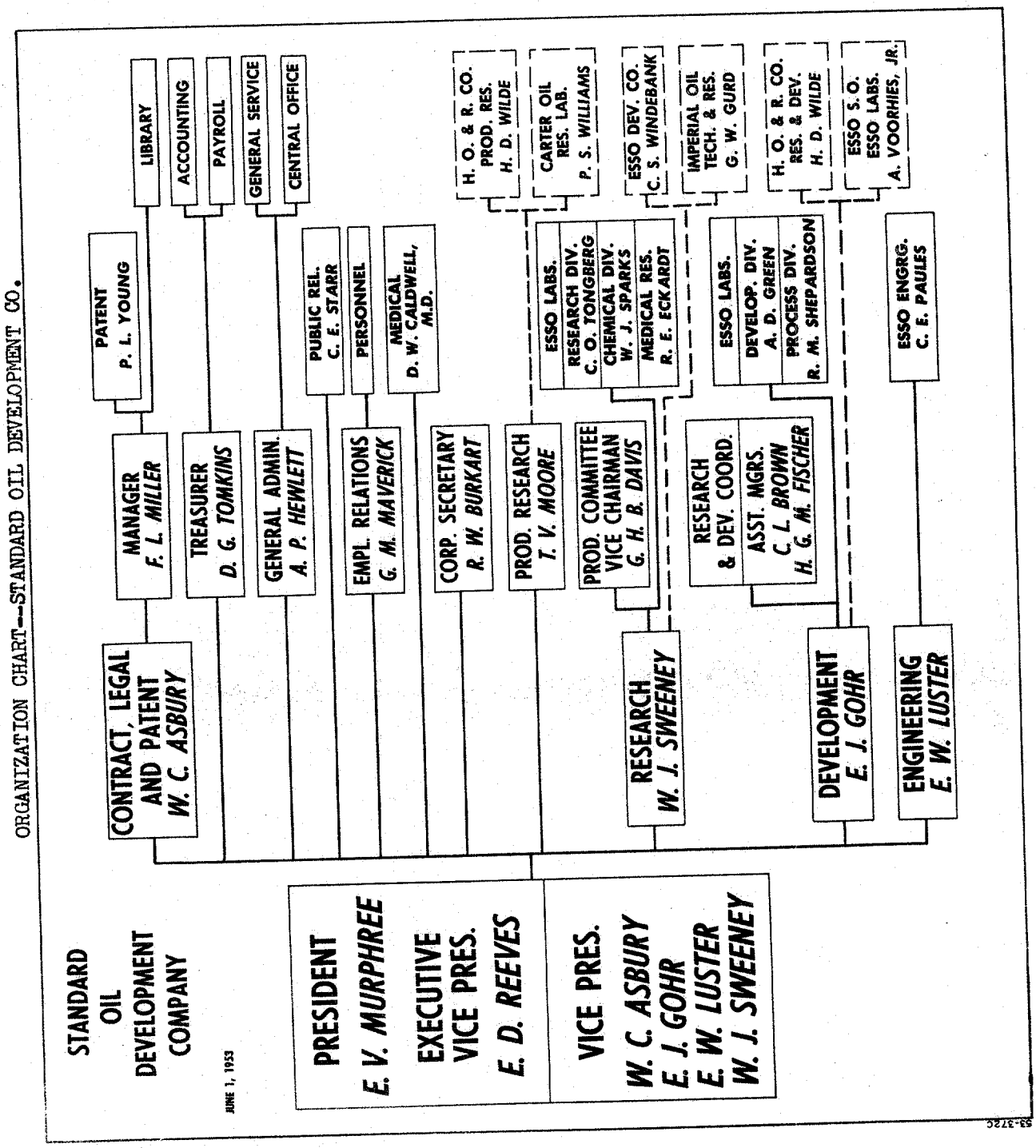
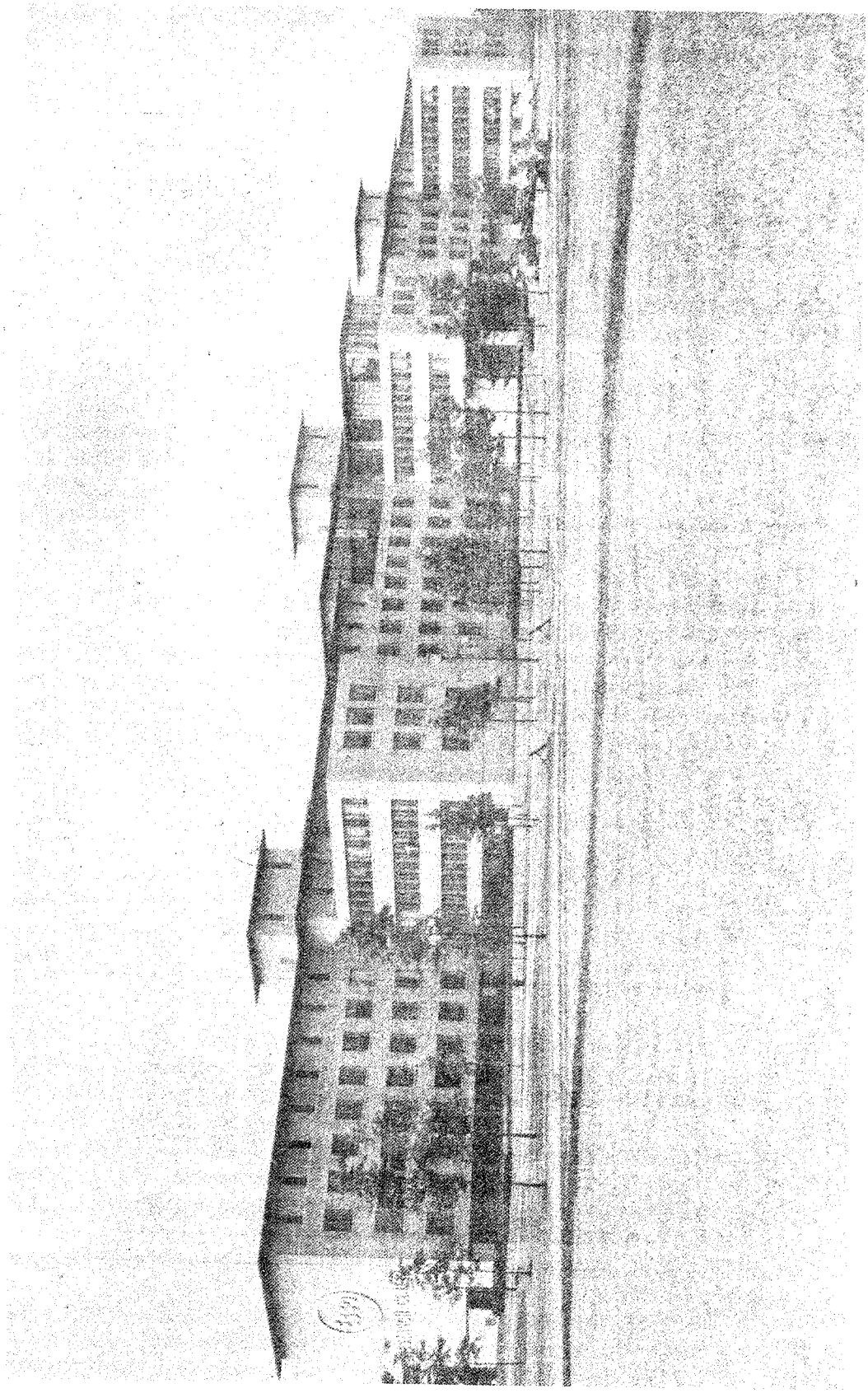
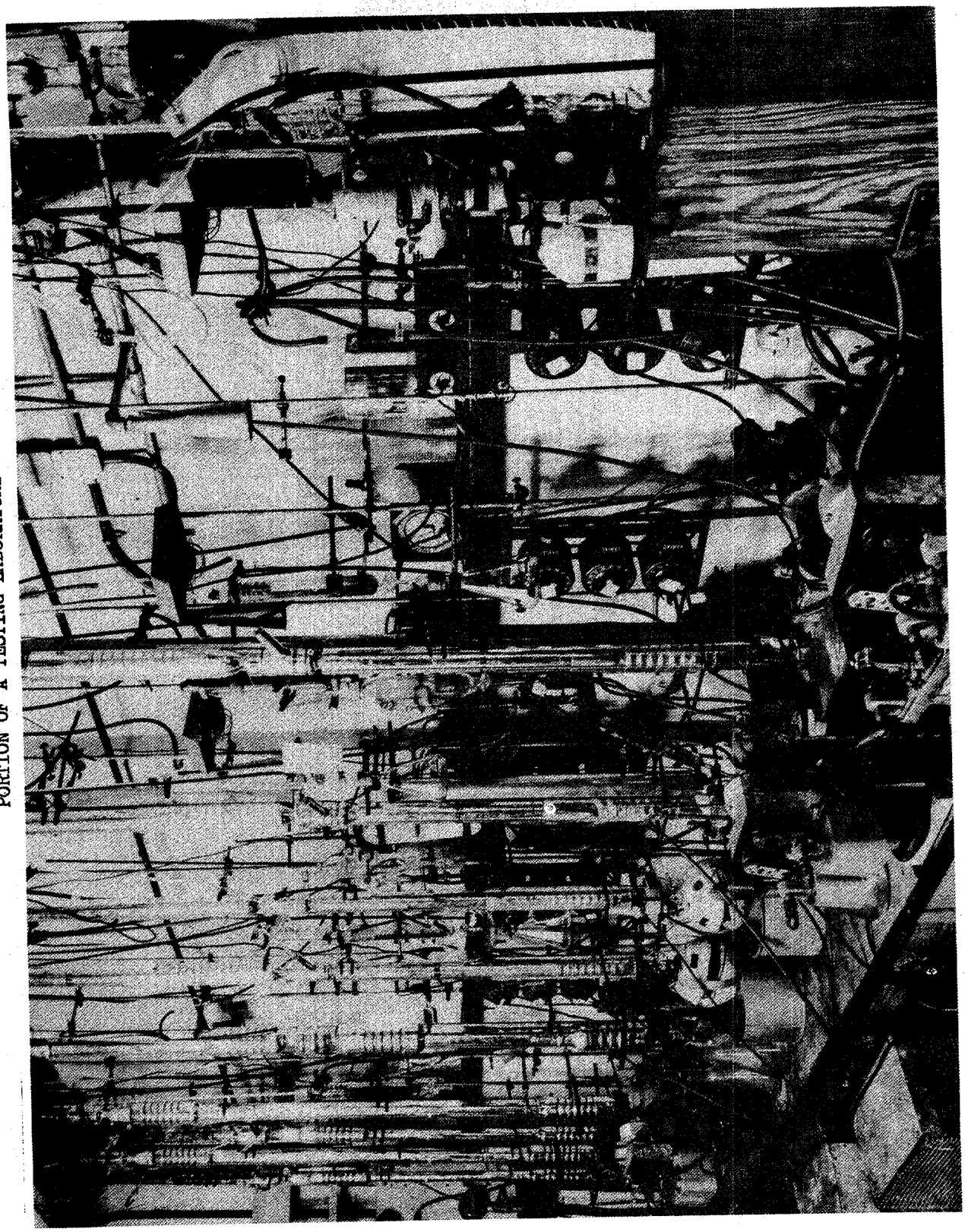

ORGANIZATION CHART--STANDARD OIL DEVELOPMENT CO.
STANDARD OIL DEVELOPMENT COMPANY
JUNE 1, 1953
PRESIDENT
E. V. MURPHREE
EXECUTIVE VICE PRES.
E. D. REEVES
VICE PRES.
W. C. ASBURY
E. J. GOHR
E. W. LUSTER
W. J. SWEENEY
CONTRACT, LEGAL AND PATENT
W. C. ASBURY
MANAGER
F. L. MILLER
PATENT
P. L. YOUNG
LIBRARY
ACCOUNTING
PAYROLL
TREASURER
D. G. TOMKINS
GENERAL SERVICE
GENERAL ADMIN.
A. P. HEWLETT
CENTRAL OFFICE
PUBLIC REL.
C. E. STARR
EMPL. RELATIONS
G. M. MAVERICK
PERSONNEL
MEDICAL
D. W. CALDWELL, M.D.
CORP. SECRETARY
R. W. BURKART
PROD. RESEARCH
T. V. MOORE
PROD. COMMITTEE VICE CHAIRMAN
G. H. B. DAVIS
RESEARCH
W. J. SWEENEY
ESSO LABS.
RESEARCH DIV.
C. O. TONGBERG
CHEMICAL DIV.
W. J. SPARKS
MEDICAL RES.
R. E. ECKARDT
H. O. & R. CO.
PROD. RES.
H. D. WILDE
CARTER OIL RES. LAB.
P. S. WILLIAMS
ESSO DEV. CO.
C. S. WINDEBANK
IMPERIAL OIL TECH. & RES.
G. W. GURD
RESEARCH & DEV. COORD.
ASST. MGRS.
C. L. BROWN
H. G. M. FISCHER
ESSO LABS.
DEVELOP. DIV.
A. D. GREEN
PROCESS DIV.
R. M. SHEPARDSON
H. O. & R. CO.
RES. & DEV.
H. D. WILDE
DEVELOPMENT
E. J. GOHR
ESSO S. O.
ESSO LABS.
A. VOORHIES, JR.
ESSO ENGRG.
C. E. PAULES
ENGINEERING
E. W. LUSTER
S3-3720

CHART 2



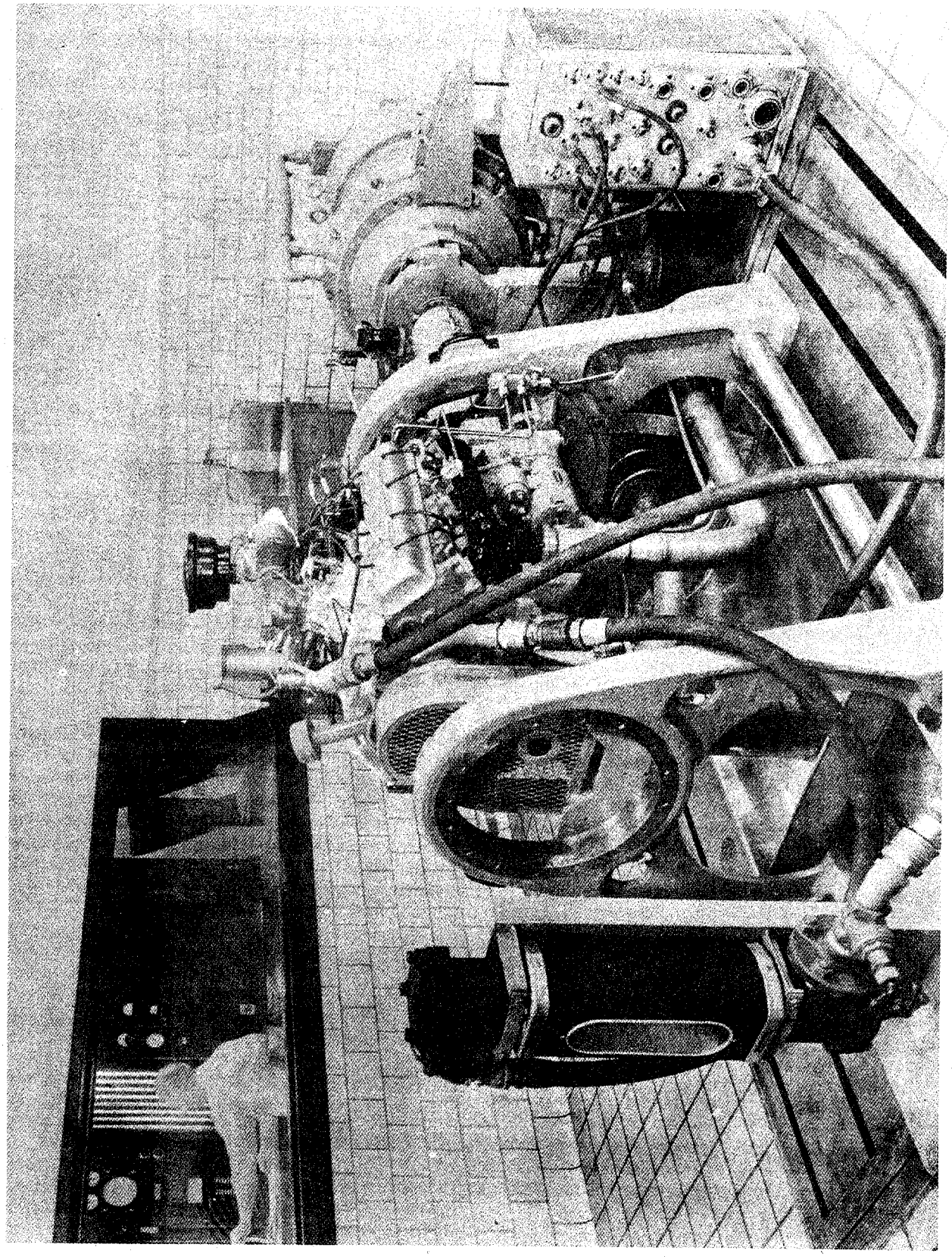
RESEARCH CENTER, LINDEN, N. J.

CHART 3



PORTION OF A TESTING LABORATORY

CHART 4



TEST ENGINE IN MOTOR LABORATORY

under controlled conditions, so we can get a pretty good idea of what they should do in the field. This Chart shows a typical testing engine in our motor laboratory. It shows an engine for testing lubricants under very severe conditions, so that in very short periods it can evaluate lubricants and sharply distinguish between those with different qualities.

I would like to call your attention in this Chart to an interesting thing about the instrumentation. You will notice that this engine is by itself and that there is a man in the next room. What he is doing is not reading the instruments. The engine is giving those readings automatically. Most of the important data are taken down on recording instruments, and the man is standing there just to see that it is running properly. We find that much better than to depend on records made by people who are constantly watching machines.

Chart 5, page 14, Pilot Plant at Baton Rouge Laboratories. Another part of our activities that requires a lot of attention is the development of new processes. You can't just put a new process into a refinery without being sure that you know how it works and what it will do. Before we can recommend to our operating people the installation of a 10- or 12-million-dollar-refinery program, we have to be very sure it will work the way we say it will. We do that in what we call pilot plants. This is a typical pilot plant at Baton Rouge, Louisiana.

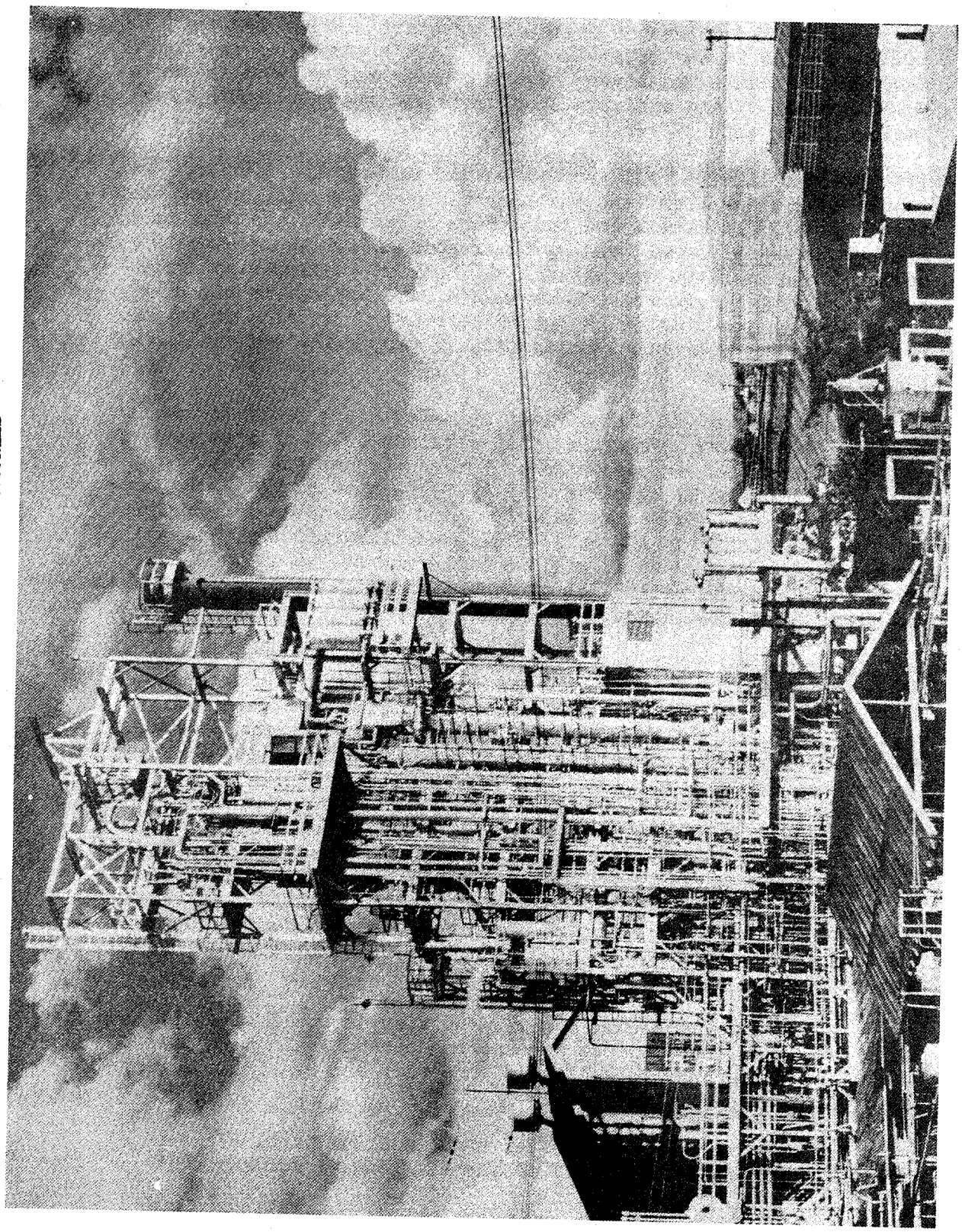
To give you some idea of perspective, this building is nine stories high. It must have an elevator, so that men and materials can get up and down the structure. Such units cost somewhere between $500,000 and $750,000 to build. They represent a very heavy investment in carrying out industrial research and development on new processes.

In addition to the facilities, we, of course, must have the people to go into the research organization. Research work today is done almost entirely by people working in teams. The problems we are faced with today are problems that individuals just can't solve by themselves. A lot of the processes that we develop in several years could not be developed in a whole lifetime of one person working alone.

Teamwork is necessary not only because it would take too much time otherwise, but also because no one person would have the technical background in all the fields that are required to solve many of these problems.

Chart 6, page 15, Simplified Organization Chart. This is a simplified organization chart of the development company. It

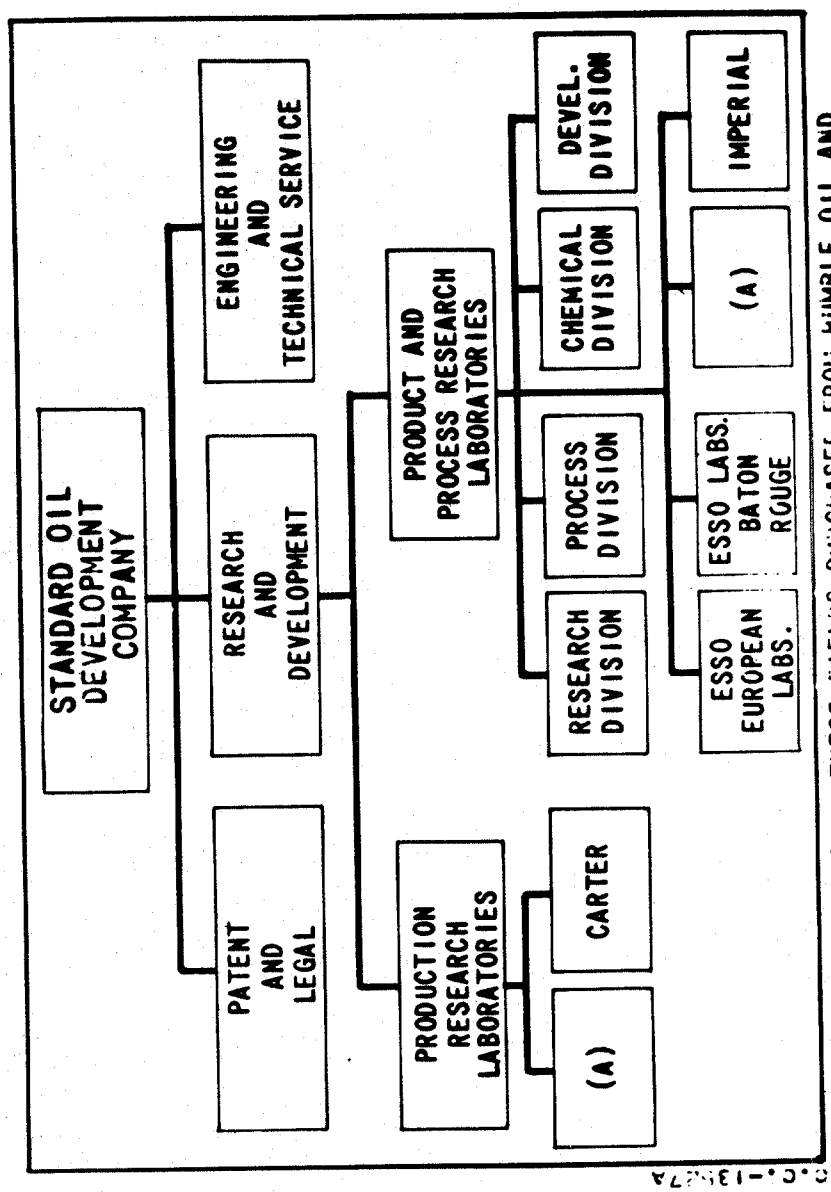
CHART 5



PILOT PLANT AT BATON ROUGE LABORATORIES

CHART 6

SIMPLIFIED ORGANIZATION CHART



(A) RESEARCH RESULTS IN THESE FIELDS PURCHASED FROM HUMBLE OIL AND REFINING CO. UNDER THE TERMS OF A GENERAL RESEARCH AGREEMENT.

shows only our main operating groups. What I would like to point out here is that about 10 years ago we embarked on the development of the fluid catalytic cracking process. We had to do it in a hurry. The war had come on. Also we could see a very definite need for it, war or no war.

In developing a process like this there are about 200 people involved. We had a great many different things to do. The Research Division had the responsibility for determining the types of products that we needed and for evaluating the experimental products developed during the course of the work. The Process Division had the responsibility for developing the basic process. The Baton Rouge laboratories developed the engineering information in their large-scale pilot plants, like the one I just showed you. We had a group called the Development Division, which is this group here, and is an engineering group. It is their responsibility to follow the research and development work from an economic standpoint. They had to be sure that the research data obtained was adequate for slant design and that the experimental work was carried out along lines that would produce an economic process when it was completed.

The Engineering Department had the responsibility for translating the laboratory pilot plant work into a practical plant design, and for supervising the construction of the plants themselves.

The Patent Department was also involved. The people in our Patent Department had to follow the work closely to be sure that we could operate the process as finally developed without being sued by everybody else and to be sure we did not infringe the patent rights of others.

Work of this kind requires many different types of people. We had organic chemists in it, inorganic chemists, physical chemists, physicists, chemical engineers and mechanical engineers, lawyers, laboratory analysts, pilot plant and engine operators, and specialists of all kinds in the design and construction of pilot plants.

I think it is perfectly obvious from all of this that in such an effort if we are going to telescope it into two or three years, we must have effective teamwork and coordination in order to do an effective research and development job and to get the things done in time for the company that needs them. The work has to be telescoped because we can't tell too far ahead of time just what is going to be needed. Maybe our customers don't know yet what they want the next new process to do. Maybe the new thing that will utilize our product has not been invented yet. It is generally difficult to predict with certainty the need for new processes and products more that two to three years ahead of time. It is very

important that we arrange to do our research and development work in such a way that we can finish it within the time allowed by the prediction so that at the time the company needs something, it will be available then and not a year later.

Another phase of this that I think is important and you ought to know about is that concerned with the management of industrial research. The management of industrial research involves many problems of its own. I would just like to touch on some of them.

I would like to mention that in addition to making sure the research organization meets the objectives I have already pointed out--that is, finding out what is needed, doing it, and applying it--that the management of research has also the responsibility for determining just how much research should be carried on by the individual divisions. It is also responsible for determining how that effort should be distributed among various fields of importance.

I think one point that should be understood here is that the value of industrial research is determined by its usefulness. It is not determined by technical success alone. The company sponsoring the research certainly gets more out of it if it can use the results in its own activities. What the sponsoring company gets out of it may be an actual process. It may be new products. It may be prestige of doing a good job, or its participation in something that contributes to the welfare of people. But it has to be useful to the company that is sponsoring it if it is going to be effective.

Also it has to be done when it is needed and on the problems that need to be solved. Industrial research certainly is unsuccessful when it does not even work on a problem that affects the company. In other words it is not enough for the research to be successful in a technical sense. It is also important that it not neglect to do the things that are going to be needed by the company.

The total effort required in industrial research varies a great deal between industries and a great deal between companies. It is determined to a large extent by the capacity of the individual industry or the individual company to utilize the results of the research. This capacity to use research depends on a great many factors. It may depend on the need by the company for a new product and for lower-cost processes that will keep it competitive. It depends on the ability of this company to finance the new plants developed by research. It depends on the capacity of the management of the company to use the research results effectively.

It has been a very interesting thing to watch different companies and see how they use new processes. We license processes to many companies, and we can see from one company to another, when a new

process is installed, that some companies build even complex plants quickly and start them right up, other companies have trouble building the same plants, and after they build them, they have trouble running them. There is a tremendous difference in the capacity of the operating people in different companies to utilize effectively the results of research in terms of new processes and new products.

The proper management of research involves a lot of judgment. It is very important that the research of a company be in balance. It is easy to tell when production gets out of balance. If production gets out of balance, products 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 industrial research. If too much research is done, the company wastes a lot of money on research. If too little is done, the company is missing the opportunity to be competitive and grow with the rest of the industry.

Also in effective industrial research you must have a balance between what we call long-range and short-range problems. If a research organization concentrates on problems that concern the company today, it will not get the answers that it will require to solve the problems of tomorrow or the next day. On the other hand if it spends all its time on so-called long-range work, on trying to solve problems that it thinks will arise 5 or 10 years in the future, it is possible that the company will not survive those 5 or 10 years and will not be able to use the results of the long-range research. So you need a balanced program that will keep the company going today and make sure that tomorrow it will be even stronger.

I think that when you look at industrial research management, you can see that the real measure of it is not so much its ability to direct the actual technical work as it is its ability to analyze all of these various problems and provide the leadership that is needed in order to see that the research organization is meeting its obligations. It also should be able to distinguish between the types of problems that the research organization should work on and the ones that should be dropped.

Now, with that as a background, I would like to go on to some examples of what can be accomplished by this type of relationship between an industry and its technology.

The oil industry is dependent on raw materials to keep going, like almost any other industry. It has been a matter of concern to a lot of people in this country that we have been using up so much oil in our wartime and peacetime activities. I think everyone is

probably interested in whether or not he will be able to get enough oil in the future for his oil burner, his automobile, and for military operations.

Chart 7, page 20, Ratio of Petroleum Reserves to Crude Oil Production, 1927-1952. This chart shows the ratio of what we call proved reserves to production over the years. You can see that it goes up and down and that it fluctuates at about a thirteen-to-one ratio.

I think you have all heard, in 1926, for example, that we were running out of oil. The same thing happened in 1936 and 1948. This has been of great concern to a great many people. The trouble is that the word "proved reserves" does not mean the same thing to the oil industry that it means to the public at large.

What is involved here is this: All over the world there are many areas that we are sure contain oil. There are some areas where we have actually drilled holes in the ground and have found that the oil really is there. There are still other more limited areas where we have not only found oil, but have drilled enough holes to measure the actual extent of that particular oil reserve and the concentration of oil in the sand. These are what we call our proved reserves. They are reserves we have actually measured and know exist in definite quantities ready for use.

Now, what we are trying to do here is to establish a raw material inventory. Any business must have an inventory of its raw materials. The size of the inventory varies considerably between industries. In some industries it may be that a 20- or 30-day inventory is sufficient. Other industries may need more than that. The problem is that if you have too low an inventory of raw materials, you are likely to run out because of a transportation strike or something like that. On the other hand if you have too large an inventory of raw materials, you have entirely too much money tied up in those raw materials and that money is not available to put into other worth-while things that the company could do. So you must have just the right balance. What we have done here in the oil industry is to try to maintain about a thirteen-to-one ratio, or a thirteen-year actual raw material inventory.

Chart 8, page 21, United States Crude Oil Production Compared with Proven Crude Reserves. This chart shows the annual production of oil and the proved reserves. You can see that in spite of the fluctuation of the ratio of proved reserves to production and in spite of the amount of oil that is being taken out of the ground, we have been continuously building up our proved reserves.

We think we have been able to do this to a large extent because of research and development. The oil industry has done a great deal

CHART 7

RATIO OF PETROLEUM RESERVES TO CRUDE OIL PRODUCTION, 1927-1952

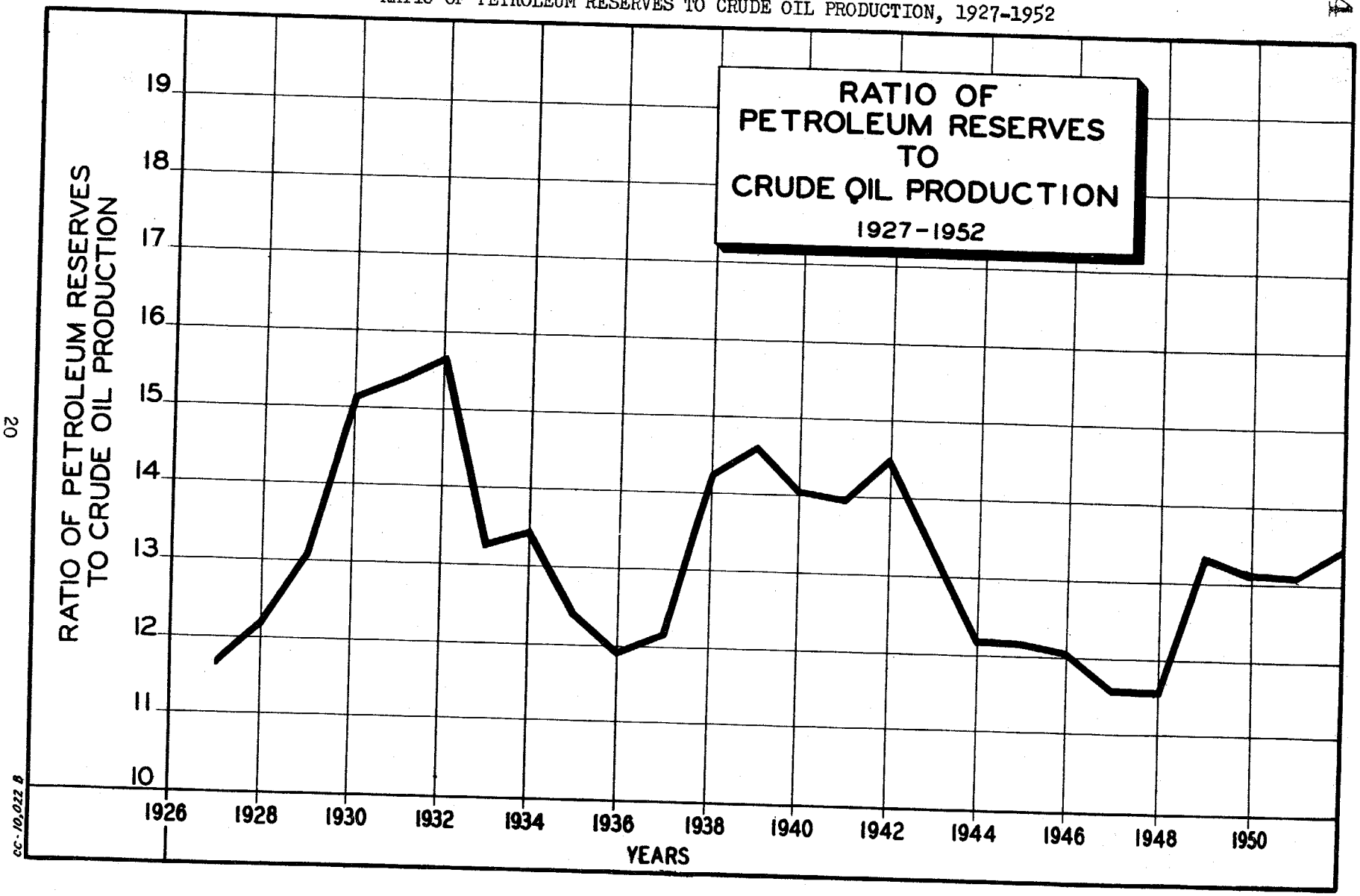


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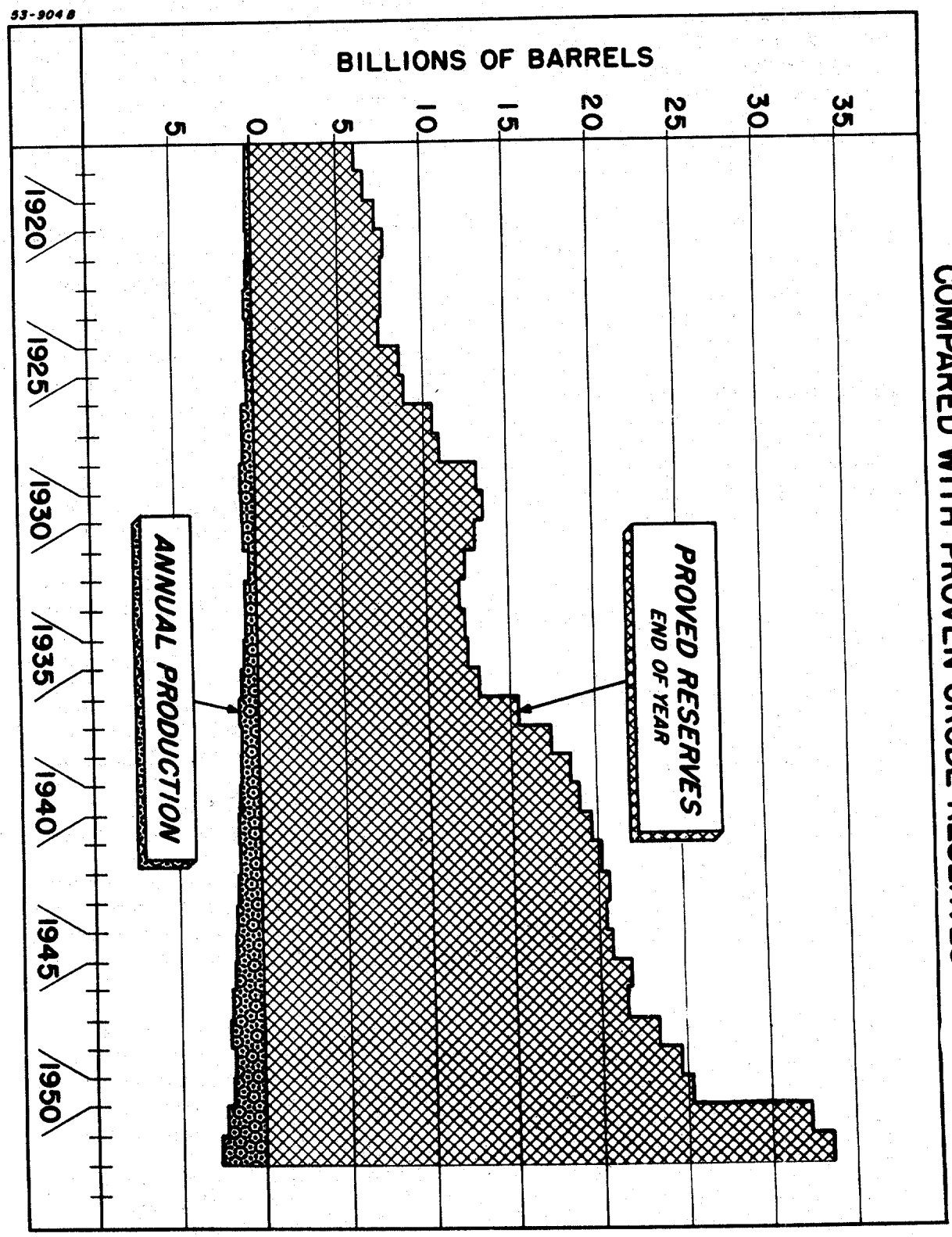
CHART 8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UNITED STATES CRUDE OIL PRODUCTION
COMPARED WITH PROVEN CRUDE RESERVES
BILLIONS OF BARRELS
35
30
25
20
15
10
5
0
5
PROVED RESERVES
END OF YEAR
ANNUAL PRODUCTION
1920
1925
1930
1935
1940
1945
1950

of research work on raw materials. Oil is harder to find now than it was 20 years ago, but we also do a much better job of finding it. It was cheaper to drill holes 20 years ago and they were much shallower. Today we do a better job with fewer holes. So as the search for oil goes on, the job becomes harder and harder, but through research the industry keeps in balance; and in terms of actual effort it is not much more difficult to find and establish new reserves today than it was 20, 30, or 40 years ago.

In addition to that, of course, the industry is quite interested in the use of other raw materials. We have always been very much interested in finding lower-cost raw materials than crude oil. We regard ourselves as suppliers of liquid energy, and would just as soon make the liquid energy from sea water as from crude oil 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 large reserves in the United States and all over the world of oil shale, natural gas, and coal, which can be converted into petroleum products. We have done a great deal of research and development work on these alternate sources of raw materials, and have developed processes which can make products from all of these fully equal in quality to those produced from petroleum.

These are not being used today, because we have not brought the cost down to the cost of doing it from petroleum. On the other hand they are close enough so that if the oil industry had to shift tomorrow to alternate raw materials, it could be done with no great increase in the cost of its products. The price of gasoline, while it would be higher than at present, would not be exorbitant and our customers could keep right on using petroleum products. We are just as concerned as anybody else about running out of raw materials. We don't intend to go out of business because of it. What we intend to do is to provide liquid energy as long as anybody wants to buy it. The raw material situation has been a very interesting thing, because the data can be so easily misunderstood. A lot of people have interpreted these data to mean that the oil industry is about to run out of its reserves and that something has to be done to conserve our energy resources. This is simply not so, and out country's reserves of liquid energy resources are far greater than is generally realized.

Another thing that illustrates what can be done by research is the development of refining processes. The oil industry has always been extremely cost-conscious. I think this is demonstrated very nicely by the fact that the cost of gasoline today, ex taxes, is not much more per gallon than it was in 1925 or 1926 in spite of all 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. The net result is that the combinations that you have of gasoline and engine today will develop about 50 percent more useful work than the combinations that were available 25 or 30 years ago.

Chart 9, page 24, U. S. Consumption of Energy by Fuels by Percentage. This chart shows the sources of energy in the United States since 1915. This shows what happens when one industry does research and another one does not. This is just a percentage chart. Actually, energy consumption has increased tremendously since that time.

You can see here that in 1915 nearly 80 percent, almost four-fifths, of the total energy in the United States came from coal. Very little came from petroleum and natural gas. A certain amount came from waterpower. Since that time coal's contribution to the energy used in the United States has gone steadily downward, and petroleum and natural gas have steadily increased.

This has been due to a great many different things. It has been due in part to the fact that the cost of manufacturing petroleum products has been going down, after allowing for inflation. In other words, 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.

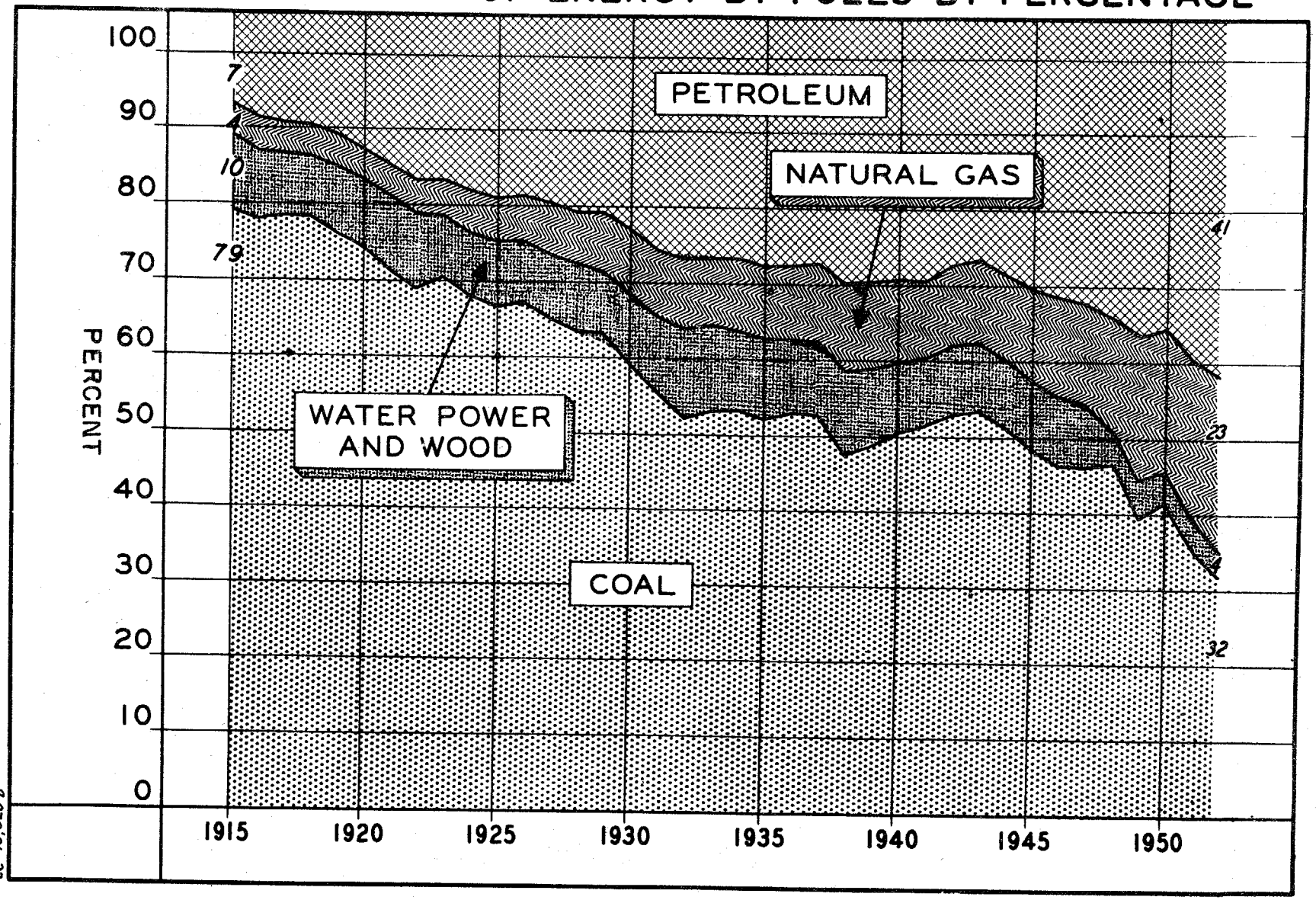
On the other hand the coal industry really has done very little research and development. It has done very little to increase the quality of its products or to cut down operating costs. We think that is one reason for the change in importance of that industry in the energy picture.

We think that these benefits have come to the oil industry because of its research and development. We think that this in turn has enabled the oil industry to provide energy products to the people at a much lower cost than they could otherwise have done.

There are a lot of examples in the products field that are interesting. I think one that is quite interesting is concerned with automobile usage. I am sure you can remember when all of our automobiles were put up on wooden blocks for the winter and left there until spring. That was due in part to the fact that the roads were no good in the winter. It was due in part to the fact that people in general weren't anxious to travel around in the wintertime. But it was also due to the fact that, even if the roads had been good and the people willing, the cars would not operate well in cold weather.

CHART 9

U.S. CONSUMPTION OF ENERGY BY FUELS BY PERCENTAGE



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The oil industry and the automobile industry have done a lot of work together to make automobiles operate just as well in winter as in summer. For the oil industry this has meant careful control of gasoline volatility and the development of new types of lubricating oils and greases to make cars operate properly. The result has been that the oil industry has really created for itself a new season in which its products can be sold. We now sell as much in winter as we do in summer.

The same is true of oil burners. We have 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. We now sell a great deal of liquid energy to railroads, which at one time operated entirely on coal.

In the same way the manufacture of chemicals by the oil industry illustrates how the industry can develop new products and increase its capacity to produce. Today we make a great many raw materials which are essential to the chemical industry. We don't sell directly to retail customers. We sell to the chemical industry.

We make ethyl alcohol from oil. It is used for industrial purposes, but it is fully equal in quality to the kind you get from fermentation. Many plastics that are produced today are derived from petroleum raw materials. We also make raw materials for synthetic fibers, such as nylon and dacron. We make most of the raw materials that go into the synthetic rubber that is used for automobile tires and inner tubes.

The automobile industry is starting to experiment with plastic bodies for cars. Some of the new cars of today are coming out with plastic instead of steel bodies. The oil industry is working with the automobile people in the development of plastics required for car bodies. Someday we will, we think, supply not only the fuel and the lubricants for the car, but possibly raw materials for most of the car itself. There are many possibilities through the development of new products for expanding our business and increasing the mileage gotten out of our raw materials.

What I have tried to emphasize here is the very intimate relationship that does exist in industry between its operations and its technology. It seems to me that technology is certainly not just the people who are in the research laboratories. It is not engineering staffs. It is not analysts. The real technology in any industry is people throughout all parts of its operations who are well trained in the technical background of that particular industry.

Furthermore, it is not formal technical training alone. Technology has to be followed by an understanding of the needs of the business, by an understanding of how to use the results of research. A technical background is important, but it is only the foundation. You must have people who know how to put it to work.

It seems to me that you have to take into account, in both peace and war, that an industry has to have the ability to move as it needs to move to meet new challenges as they arise. Certainly during peacetime no individual company can expect its competitors to follow rules that it would like them to follow. Each company tries to figure out how to get the jump on somebody else and do things better. If you stand still, you will find the others going ahead of you.

I think the same thing is certainly true of war. You can't fight a war and expect your opponent to stick by the rules that you set up for warfare. Things constantly change, even during the course of a war. This is well illustrated by what happened during the last war, when our supply of natural rubber was unexpectedly cut off. When that happened, within a very short period my own industry converted a lot of its operations to supply the raw material for the synthetic rubber which replaced natural rubber. It has been fully the equal, I think, if not better than natural rubber.

The same thing was true of other parts of our industry. On demand we supplied special fuels, lubricants, and petroleum products of all sorts, as the war progressed. These greater demands were not anticipated before the war started. Some of these things were developed as the war went on. You have to be flexible in all of these activities, in both peace and war, to cope with new and unexpected challenges and do it effectively.

In summary I would just like to touch upon some of the things that, it seems to me, are important for you to consider about technological progress within industry. This may be somewhat of a recapitulation. But I do think that in the United States industrial technology is starting to affect all of us to a very great extent. Compared to a while ago, it is having a tremendous impact on our lives and on our standard of living.

This has been done largely by the growth of technology in American industry. Some years ago industry could survive by taking or leaving technical developments. You could refuse to do things better and still get along. You can't do that today. You have to use technology as a part of your own competitive strength.

I think that this combination of business initiative and industrial technology is what is going to result in our long-range security. I think the capacity that we have built up to produce in peacetime and meet the challenges of peacetime will be the same capacity with which we can protect ourselves in the event of an aggression in the future.

CAPTAIN SWAIN: Mr. Reeves is ready for your questions.

QUESTION: Mr. Reeves, I was wondering why you found it necessary to set up a separate organization for your development work. It seems to me that this is somewhat inconsistent with the statement you made earlier in your talk--that research and development have to be an integral part of the production side.

MR. REEVES: Of course, it differs from company to company. The company I am talking about is the Standard Oil Company (New Jersey). It operates all over the world except for some parts of the United States and in Russia. It has facilities everywhere.

In 1911 there was only one company, the Standard Oil Company, which did about 95 percent of the oil business. The courts thought it was too large, so they broke it up into a number of different companies. When they did that, each company said it wanted to use the name "Standard Oil Company." This problem was solved by assigning a certain territory in the United States to each company. Then each could call itself "Standard Oil Company" in that particular territory. The Standard Oil Company (New Jersey), which is the one that I work for, was given the eastern part of the United States.

These companies can market their products in any place they want to, but in the United States they can't use the name "Standard Oil" anywhere except in their own territory. These companies, even though they carry the same general name, operate entirely independently in the different areas.

The Standard Oil Company (New Jersey) has grown tremendously since the breakup. It has facilities in and is operating in all parts of the world except Russia. We have the Creole Company in Venezuela, the Imperial Oil Company in Canada, we own three-quarters of the stock in the Humble Company in Texas, we have a company in England, Belgium, Germany, Italy, Africa, Australia, and so on.

These companies all have very similar problems and it is very affective to work on the problems on a unified basis. So the development company was set up to do that effectively.

We are a separate company. We do not work with the operating companies through the holding company. We are a research and development company, an individual operating company. We think that is very important, because the Jersey holding company just handles the Jersey overall affairs. It lets each company run its own business.

It is not sound practice for Jersey's operating companies to get research and development information from their stockholders. Each company must have the ability to get the information for itself and to make its own decisions. It has to be able to tell the central management what it thinks it should do and then do it.

What we have done is, set up a research and development organization for about 20 or 25 different operating companies. We work for each one of those as if we were a part of its research organization. We talk to the management of each company. We talk to the technical people in each company and we talk to the operating people in each company.

If Esso Petroleum in England wants to build a refinery, it sends its people over to work with us on the design of the refinery. We also help on its construction and operation. The same thing would be true in Africa or anywhere else. In other words we send people all over the world to work with the people in the operating companies. In that way we achieve an identification with them which is the same as if we were their own research and development organization. But we have the added advantage that we have a much broader base and can afford to do many things in the development of new processes and new products which the individual companies themselves could not afford to do.

Somebody said: "What do you do for the smaller companies in the oil business?" The Jersey Company as a matter of policy licenses its developments at a reasonable royalty. We don't attempt to get back in royalties what it costs us to make those developments.

We do that, I think, as a matter of self-interest. It is true that these small companies can compete with the large companies very effectively except in the area of research and development. We think it is to our own interest to keep the industry healthy. We don't think it would be healthy if the smaller companies were putting out products to consumers that were not of satisfactory quality. So we like to see them use the same technical developments that we do. Our aim is to keep the industry healthy, so that in turn we will have a better environment in which to maintain ourselves.

QUESTION: I am interested in the conservation of resources. Private industry handles the liquid resources in the energy field and it also handles most of the research and technical advances. Let us say that one private company has developed an item with no extra cost per gallon of gasoline which will increase the effectiveness of that fuel so you could get 100 miles to the gallon of gas instead of 15 miles. What would be the moral obligation of that company, or what would be the reaction, let us say, of that company, to such a tremendous technological advance? What would be your course of action?

MR. REEVES: That would be a pretty nice development. Our thinking is like this:

In the first place I think that all corporations these days recognize that they have a major responsibility to be a good citizen. In other words if a company should consider only its own self-interest in doing things, it would react to the detriment of the country in general. Industry realizes that in the long run it is going to suffer by that. So almost all corporations do recognize an overriding responsibility to our system of free enterprise and a responsibility to help build up a healthy environment in which to work.

I would say that in general most of the companies that I am familiar with would try to put to work right away anything that they considered to be an important development. In other words, in this competitive economy that we are living in, if one company finds something that is good, it usually springs it. There may have been instances where some industry or company made a development and put it on the shelf, but that hasn't been my experience. I don't know of any companies doing that. Most companies figure out a way to use their new developments right away.

When a company develops something and seemingly puts it on the shelf, there is usually a reason for it. Maybe it is not economical. For example, we have ways for making petroleum products out of shale oil. We have ways of making it out of coal. Some people may feel that, since we are not actually doing it, what we are doing is putting it on the shelf and thus retarding the development of the country.

That is not so. The reason we don't do it is we don't know how to make money out of doing it. If we find a cheaper way of making petroleum out of oil shale, we will be the first to bring it out. We don't care where we get our raw materials. All we are interested in is selling liquid energy. We can sell more liquid energy and of better quality when the cost is low. That being our objective, I think we would just be cutting our own throats if we made an important development and put it on the shelf.

QUESTION: That was my point exactly. But in this matter of having a development of that sort, which may be of great significance to the future security of the country, it may be entirely possible that it might be to the advantage of the economy and the country to actually shelve this item and hold it in top secrecy for the benefit of our future needs. Do you have or is there in the Government of this country an agency that you can work with, or do you feel that there is need for an agency of the Government to work with you and decide whether a technical development should not be placed on the market at the time that it may come out?

MR. REEVES: There are agencies of the Government that we can work with. I can cite this as an example: We have developed a process called the butyl rubber process. That process was used during the war for the making of inner tubes for passenger cars.

We have felt that butyl rubber can be used for the tire itself. We have done a lot of work on the development of butyl rubber for passenger car tires as well as inner tubes. The development work that we have done thus far indicates that you can make a better tire out of butyl rubber than GRS. It could be used for tires on trucks and jeeps in field service. Butyl rubber won't deteriorate under long service like some other rubbers. So we recognize the importance of it from the military standpoint. We have gone to the armed services and told them all of the advantages and what it means to them. We have told them that we don't intend to make butyl rubber tires, because we are not in the tire business. We are interested in the tire companies using butyl rubber as a raw material.

As to the rest of your question, I don't think it is a good idea to shelve things in the interest of national security, because I don't think you serve national security by doing that. I don't think cutting down petroleum production is a good way to save oil. The way to make oil available is by using it, by having the capacity to use it in existence.

In our organization we don't look on secrecy as being a valuable tool. This is a personal opinion, but I look upon even this atomic energy business as being too secret. I think that our development would be more effective today had we not had such stringent secrecy.

Anyway, I think that what you do when you take something and put it under secrecy is to immediately stop all further development. A lot of things may be more important than to keep it secret. Further development may be more important. If you don't keep things secret, you may have a more effective tool later on.

QUESTION: To what extent in general is research and development information exchanged between commercial companies?

MR. REEVES: Research and development information is like a lot of other business information. We will, for example, at times give development people in other industries a lot of research and development information; but we do that with the idea in mind of persuading them to carry through the development of something that we think will be of equal benefit to both of us.

We are developing fuels; and we do that by working with the automobile industry in their development of engines. We have to work through them so that we can give our own customers a better gasoline or oil. We have followed the policy of keeping the automobile people informed as to what we can do in the way of developing better fuels for them. We also hope that in turn they will tell us what they are thinking and what we can do in the way of research on the kinds of products that they need in their cars.

So between industries there is a certain amount of exchange of technical information; but it is always done, you might say, for selfish purposes. In other words we give them information for the simple reason that we think that by benefiting them it will help us in the long run.

We don't exchange information between companies in our own industry except on a license basis. We do license freely. When we license something, we give the technical information that goes with that license.

It happens from time to time that as a new process or a new product is being developed, there is one company that is pretty well along on one part of it, and another company has another part pretty well in hand. It may look as if the whole development cannot be made available unless these people get together. In such a case they do try to get together. Then if the development is successful, it is made available to others on a license basis. But the exchanges are always done on an individual basis, and are usually done with the idea of getting more than you give.

QUESTION: As a continuing matter what percent of your gross income dollar must be devoted to research and development? As a related matter, What is the effect of giving the industry tax advantages on your research and development program?

MR. REEVES: The oil industry in general is spending about seven-eights of 1 percent of its sales on research. That may not sound like much, but the sales are very large. In some individual cases it may be as high as 3 or 4 percent.

On your second question, the effect of tax advantages, I think it would be fairly small. Most research and development work is carried on as operating expense. The higher the taxes, of course, the less money we have to spend. But that also applies to both our income and our research and development money. So I don't think lowering the taxes would make much difference.

CAPTAIN SWAIN: I am sorry. That is all we have time for.

Mr. Reeves, you have done a wonderful job of covering our subject for us. On behalf of the students and the faculty I thank you for a most stimulating and interesting lecture.

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