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PETROLEUM--WORLD RESERVES, PRODUCTION, MANUFACTURE AND USE

1 March 1949

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PRODUCTION, MANUFACTURE AND USE

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GENERAL VANAMAN: Gentlemen: Napoleon knew and stated that armies travel on their stomachs. We know that the modern military machine moves on petroleum products. Our overseas shipping tonnage of petroleum products in World War II exceeded that of the arms, ammunition, food, clothing, shelter, and equipment, all of it combined. You can see the importance of petroleum products.

We all know from his biography and from his history and from the many things that have been written about General Doolittle of his outstanding qualifications to talk with us this morning on this very important subject. General Doolittle started his career in the technical field underground as a mining engineer. He then made his reputation above ground in the air and now he has returned to a combination of on the ground and underneath the ground.

It gives me great pleasure to introduce to the Industrial College of the Armed Forces and to our guests, General James H. Doolittle.

GENERAL DOOLITTLE: Thank you very much, General Vanaman. General Vanaman asked me to talk to you gentlemen about the petroleum industry. To cover the subject even sketchily in the limited time that has been allotted to me is a very large order indeed, so I have jotted down a few notes to assure continuity to my talk and have about 21 charts that I would like to show, feeling that through these charts it will be possible to give the information far more quickly than through words alone. Also I have a few extra charts that I hope will answer questions should any be asked after I am through with my remarks.

I want to speak first about industry in general and will use the petroleum industry as a basis on which to give my impressions.

Chart 1, page 23.--The petroleum industry is broken up into five basic functions: Exploration, which is the search for oil; production, which is drilling for oil and bringing the oil to the surface; manufacturing, which is converting the oil into its various useful forms; transportation, which includes the transportation of crude petroleum and the transportation of products; and last, marketing, which is the distribution and sale of petroleum products.

There are also two general functions, research and administration, which deal with all of the basic functions.

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About 25 percent of all the industrial research that is done in the United States is done by and for the petroleum industry. Petroleum research can be broken down into two fundamental parts: product research, or research on the development, improvement, and use of products; and process research, which is research directed to the end of improving refining methods.

Petroleum research is sometimes considered under the three general subheadings: oil, chemical, and general.

Oil research deals with hydrocarbons in general and includes research in connection with the basic functions: exploration, production, and manufacturing.

Chemical research deals largely with materials derived from petroleum which are not wholly hydrocarbons. Petroleum chemicals have many industri uses. They are used in synthetic rubber, plastics, detergents, solvents, etc. One of the really large fields for petroleum chemistry is in agriculture. From petroleum-base materials are made fertilizers, selective weed controls, insecticides, fungicides, nematocides and various growth-control chemicals. It is possible through chemical application to keep a tree from blossoming until the spring frosts are over so that the blossoms are not nipped and the fruit lost. It is possible to keep the fruit on the tree until it ripens fully and then to put on a preservative which permits the fruit to be shipped tree-ripened instead of ripening off the tree during shipment. This means better, sweeter fruit.

General research deals with basic or fundamental research and with the development of the tools and instrumentation necessary to do research.

Administration, the other general function, deals with planning, finances, legal problems, public relations, industrial relations, personne and so forth. A great deal of research and fine constructive thinking is being done in connection with personnel relations in order to improve the relationship between employee and employer to the end of increasing productivity; and, at the same time, giving each individual the opportunit for advancement and enjoyment in his work.

Industry, in general--I am talking, I realize, in a very elementary way to many of you folks, but I feel these initial remarks are necessary in order to clarify things that will come up later--is very like the conventional line and staff military organization. The head office in many industrial organizations corresponds almost exactly to the general headquarters in a military organization. Marketing divisions correspond, I should say, to the combat units in the field, although it is perhaps a bad analogy to consider customers as "enemies." There are the same

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problems, the same misunderstandings between the headquarters and the field units in a military organization and between the home office and the division offices of an industrial organization. The field units always feel that the headquarters are not particularly interested in, or are not cognizant of, their local problems and the headquarters always feel that the field units are inclined to give too much importance to their local problems and lose sight of the over-all picture.

When I went into industry in 1930, some 19 years ago, I frequently heard the statement made that the primary purpose of any business is to make money. That concept is completely changed. No business can remain in business and remain successful if its sole purpose is to make money. The primary purpose of any industry is to render a necessary public service. It must make money in order to continue in business and so continue to provide that service, but the making of money is a means to the end and not the end. That is a very important change in industrial outlook and is an extremely healthy sign.

Industry's responsibility is fourfold: First, responsibility to stockholders--the stockholders must get a fair return on their investment. Secondly, responsibility to employees--they must get a fair wage and proper treatment. Thirdly, responsibility to customers--they must get a good product at a fair price. Fourthly, and perhaps most important, industry's responsibility to the public at large--every industry must have an interest in civic affairs and must be an influence for public good.

I am going to say just a few words on the history of petroleum and then skip on. Petroleum was mentioned in the Bible. It was first used perhaps some 5,000 years ago in Babylon as a binder for mortar. Its first recorded war use was in 420 BC in the siege of Plataea, where fascines (bundles of sticks) were saturated in petroleum pitch and sulphur, then piled against the walls of the city and burned. In about 400 AD, "Greek Fire"--petroleum pitch mixed with finely divided quicklime which, when exposed to moisture ignited spontaneously--was used very effectively. In ancient times, petroleum was used for mummifying, waterproofing, mortar, medicine, burning; and, after the invention of the wheel, as a lubricant. In 1415, it was considered or used for street lighting in the city of London. In 1810, it was first distilled into coal oil and used in place of the sperm oil, which had been used previously for lighting.

In 1859, the first well was drilled for oil by Edwin S. Drake near Titusville in Pennsylvania. Oddly enough, oil had often been encountered before when drilling for water or salt brine, but this was the first well drilled in the hope of striking oil. Earlier "oil" wells were abandoned with disgust because the oil polluted the water or spoiled the salt.

A hundred years ago petroleum was used largely as a medicine, with some slight usage as a fuel and for light. Fifty years ago it was used primarily for light and fuel. Today it is fifth among United States industries and it is used for a multitude of purposes.

Perhaps the questions that we can get the most argument on are "What is petroleum? Where does it come from? What caused it?"

Petroleum is a complex mixture of hydrocarbons and impurities. The principal impurities are sulphur, nitrogen, oxygen, and various other inorganic materials. It comes as a gas, liquid, and solid. The simplest hydrocarbon is CH_4 (methane). The most complicated hydrocarbon molecule has a thousand or more C atoms. In the range C_5 to C_{12}, we find gasoline C_{12} to C_{18}, kerosene; C_{18} to C_{21}, Diesel fuel and heating fuel. Lube oil materials cover the general range C_{20} to C_{35}, and go up to C_{50} in the heavier industrial and aviation oils.

Petroleum is roughly 85 percent carbon and 15 percent hydrogen. Some petroleum compounds are extremely complicated, so complicated that today we have isolated and identified only about one percent of the total number of compounds found in crude petroleum. As you know, crude oils vary greatly; from light, almost colorless nonviscous liquids to heavy, almost solid black tars. The value of the crude oil is determined largely by the lighter components. A light crude is ordinarily more valuable than a heavy crude. Incidentally, in Canada some raw crudes are so light that they can go direct from the well and be used in farm equipment.

Chart 2, page 24.--There are various theories as to the origin of petroleum. Perhaps the most tenable of all these theories is that it resulted from the decomposition of organic matter, probably roughly 90 percent microorganisms and 10 percent fish, animal and vegetable matter in salt water basins. This was covered successively by layer after layer of silt in sedimentary basins. This all occurred millions of years ago. As the weight of the overlying layers of sediment increased, the crude petroleum, resulting from the composition of the organic matter, was squeezed out of the clayey beds into the neighboring sands. In these sands it was trapped sometimes--and sometimes not--under an impervious overlay. Petroleum is not found in lakes or underground channels. It is found largely in sandstone and limestone, in the porous spaces between the sandstone and limestone particles. Petroleum--and some water--constitutes from 35 percent of the volume in extremely porous material down to one percent in material that is nearly impervious. Petroleum is commonly found in anticlines, faults, and stratigraphic traps. Chart 2 shows what these structures look like.

Chart 3, page 25.--Now after that preamble I will get down to the real meat of my talk. This chart shows the producing and possible producing areas of the world. In black, you will see areas that are already producing; and in crosshatch, possible producing areas. You will notice that in both North and South America there are very substantial potential producing areas. A point of particular interest is the tremendous potential in Russia.

Chart 4, page 26.--This chart shows the producing areas in the United States and the potential gas and oil areas. You will notice one little piece up on the Atlantic Seaboard which is a potential producing area but which has not yet produced any oil. You will see the substantial potential producing area in and adjacent to Florida. However, very little oil has been produced in Florida; last year just under 300,000 barrels of oil was produced there. The tidelands off Florida, off Mississippi, off Louisiana, off Texas, as well as off California, show tremendous potentialities. Some of the tideland area off Texas, Louisiana and California has been explored and has been proved to be oil producing. The tidelands off Florida have not yet been extensively explored, so their value is problematical. It is impossible to say where oil is prior to drilling. You can say only where oil might be. If the traps were not formed, or if they were not present when the oil migrated, if the oil leaked out during the ages between the time it was formed and the present, there will be no oil.

Chart 5, page 27.--The exploration for oil is an extremely interesting part of the petroleum industry's work. It is nowadays customary to first fly over potential oil territory and look it over from the air. It is possible to tell a great deal from the outcroppings; sometimes possible to get an idea as to the general structure. An expert can get valuable information from the type and distribution of vegetation. In the polar areas--I was up at Point Barrow, where the Navy is exploring for oil, last August--it is possible to tell the areas of permafrost from the vegetation. Permafrost refers to ground which is completely frozen all the time except for the top foot or a foot and a half which thaws during the summer months. If there are any beech trees, you know the ground is not permanently frozen because these trees have deep roots and cannot grow in the shallow soil above permanently frozen ground.

Through the use of aerial photography it is possible to get an even better indication of the type of soil, topographic features of the terrain and the general geology of the country. Through a study of aerial photographs and careful interpretation by trained specialists much valuable information may be obtained.

Aerial reconnaissance is ordinarily followed by ground geological parties who study surface indications employing conventional geological methods.

It is necessary to resort to core drilling, which is more expensive, if it is desired to determine, for sure, what is under the surface. Ordinarily such drilling is carried only to shallow depths; under 1,000 feet, but can give valuable information regarding the formation and structure immediately under the surface.

Geophysical methods are now extensively used in exploration. The most important techniques employed are seismic, gravimetric and magnetic. In the seismic method a dynamite charge is set off and the reflected waves are picked up and analyzed. A soft surface like clay tends to absorb the waves and return a weak reflection. On the other hand, a hard surface, for instance limestone, reflects the waves well and causes a definite zigzag line on the seismograph. Through accurate interpretation of the seismograph recordings and by shooting enough holes, it is possible to get a topographic indication of the underlying formations and structures. Incidentally, "formation" deals with the geological age of the layers, and "structure" deals with their shape and configuration.

The gravity meter measures the gravity of the earth's surface. In an anticline, with a center of dense and heavy material such as limestone, the gravity meter will give a higher reading directly over the top of the anticline than over the lighter material on either side.

The magnetometer operates similarly, but in this case the earth's magnetic forces are measured. These magnetic forces are determined by the amount and disposition of the magnetic materials in the various layers. Here again it is possible to get an indication regarding subsurface structure. Recently very rapid magnetic surveys have been made by towing a magnetometer behind an airplane and getting a continuous reading.

Gravimetric exploration in the marshy Gulf Coast areas has been carried out under great difficulty. Often there is not enough water for boats, and still the ground is too soft to support vehicles--even caterpillar tractors. Here helicopters have been used very effectively. By having a hole in the bottom of the helicopter, it is possible to land the helicopter on floats; push the gravitometer, on its tripod, through the hole and take readings in a matter of seconds without even stopping the motor. By hopping from point to point in this way, it is possible to speed up a gravimetric survey roughly ten times. Wartime Shoran is being used to locate accurately and permit plotting of the points where readings have been taken.

All of these methods indicate where oil may be found, but the final proof is in drilling--and nobody has yet found a way of telling where oil is except by drilling. However, drilling is very expensive. It is a gamble so, consequently, all practical scientific methods are used in order to make it the best possible gamble.

Chart 6, page 28.--Relative drilling costs are indicated on this chart. The deeper the well the more it costs per foot to drill the well. Drake's well was 69.5 feet deep and according to today's standards was a very cheap well indeed. The wells in the east Texas area have an average depth of around 3,600 feet and at $8 a foot, as given in this chart, would cost about $30,000 per well. In west Texas, the average depth of wells being drilled today is around 10,000 feet, and you will see from the chart that at $16 per foot the cost is in the order of $160,000 per well. At $160,000 a well, it is easy to appreciate the necessity for taking every possible scientific precaution to hit oil. The deepest well in the world is now being drilled in California. In mid-February it was 18,414 feet deep. According to the chart that would have cost on the order of half a million dollars to date--and they have not yet struck oil or a favorable oil structure. Actually the well has probably cost much more than a half million.

The rate at which the drill penetrates depends upon the hardness and nature of the material through which you are drilling. Drilling may be as slow as two or three inches a day. As a matter of fact, we had one experience where drilling was so slow that there was some question whether we were making any progress at all. Finally the drill stem was pulled up and it was found that progress had been made. We had made a little more than an inch. That much wore off the drill bit.

Under extremely favorable conditions, going through soft material, as much as 2,000 feet a day can be drilled. In a deep well, drilled through hard materials or under usual conditions, it is possible to spend over a million dollars on a single well. The drilling rigs themselves--of course, the walking beam and cable rig is seldom, if ever, used today; it is all rotary drilling now--cost from $15,000 to $600,000. Floating rigs of the type used in the swamp lands of Louisiana cost around $900,000, and the rigs and platforms that are being used to drill in the tideland areas off the Gulf of Mexico, cost up to $1,250,000.

Chart 7, page 29.--The percentage of dry holes that are being drilled is increasing. This chart shows that in 1920 just over 20 percent of the holes drilled were dry. A median straight line from 1920 to 1948 indicates that over 30 percent of the holes that are being drilled today may be expected to be dry. This increase in the ratio of dry holes is occurring despite the tremendous advances in technological knowledge

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and the great improvement in exploration methods. It gives an indication as to how much more difficult it is becoming to find oil. In 1948 there were 6,877 wildcat wells drilled and 81.4 percent were dry holes. That is, over four-fifths of the wildcat wells drilled last year were dry hole Actually almost 40,000 wells were drilled in 1948. Most of these were drilled in order to improve property that was already producing. Those are called exploitation wells. The wildcat wells are called exploration wells.

Chart 8, page 30.--This chart shows the proved crude oil reserves in the United States from 1926 to 1948. You will notice that in 1948 there was a substantial increase. This heartening increase was directly attributable to the stable market and the satisfactorily high price of crude and of petroleum products. This encouraged exploration and exploitation, and also had the effect of making marginal producing areas economically useful. About 57 percent of the United States crude reserve are in Texas, 14 percent in California, and 29 percent in the other state Principal among the other states are Oklahoma and Louisiana. Louisiana is becoming an increasingly important oil-producing state. Last year Oklahoma appeared to be very much on the decline, but recent discoveries in there have given Oklahoma a new lease on life.

In 1937, there were 2,300 wildcat wells drilled for 3,722,000,000 barrels of crude, or about 1,600,000 barrels per well. In 1947, there were 5,800 wildcat wells drilled for 2,400,000,000 barrels, which is about two-thirds of the amount of oil that was found in 1937, for 2.5 times the number of oil wells, or a total of 420,000 barrels per well. The ratio of oil found to wells drilled has therefore declined in the ratio of four to one. While these statistics do not tell the whole story, the fact is that it has become about four times as hard to find oil in the 10 years between 1937 and 1947.

Chart 9, page 31.--The world crude oil reserves are shown on this chart. You will notice a slight hiatus here. It shows for 1948 about a 23-billion-barrel reserve instead of 25 billion for the United States. The explanation is that this chart does not include condensates from natural gas, as they are not included in the reserve figures for other parts of the world. We have only considered them here for the last few years since conservation indicated the necessity for putting in absorptio plants. Condensates were not included in this chart in order to make the United States reserves comparable with those of other parts of the world.

You will notice that North America, which has been very well explored has about 30 percent of the total crude oil reserves of the world. Venezuela, which is developing rapidly, has 13 percent. The Middle East now has 42-plus percent and has not been explored to anywhere near the

extent that the United States has. We can therefore expect, under more extensive exploration and exploitation, a very substantial increase in the Middle East reserve. Russian controlled crude reserves are problematical, but the best guess we have is about 11 percent of the world total. That includes not only the area in Baku above the Caspian in Russia proper, but the Romanian oil fields and the others which they now control. The reserves in the rest of the world represent, as you see, a very small percentage of the total.

Chart 10, page 32.--This chart shows the United States crude oil production from 1926 through 1948. Previously, on chart 8, you remember, we saw the United States proved oil reserves. The production last year was just over two billion barrels, or about 8 percent of our total proved reserves. Last year 39,770 wells were drilled. Production increased 8.5 percent over 1947 but 20 percent more wells were drilled. The total oil wells that are producing in the United States today are 413,000 plus, for an average per well of about 14 barrels per day.

Chart 11, page 33.--This chart shows the crude oil production for the world for 1938, 1947, and 1948. You will notice that the increase in the United States has been considerable. It has been relatively greater in Venezuela and relatively greatest in the Middle East. Only in the Russian controlled areas and in the East Indies, where the oil fields were destroyed as a result of the war, has there been no increase over 1938. In the East Indies the Allies destroyed the oil wells when they moved out. The Japanese restored them; the Allies bombed them; the Japanese moved out and destroyed them when they moved out, so they have really been destroyed three times. "Others" on the chart are largely the East Indies. You will see that in 1948 they are not yet up to what they were ten years ago, although they are building up rapidly. The same thing is true in the Russian controlled areas.

It is interesting to note that crude oil production in the United States is in the order of 61 percent of the world total, whereas proved reserves are less than 30 percent. In the Middle East crude oil production is only 12 percent of the world total, whereas proved reserves are over 40 percent. This indicates very conclusively our dwindling resources and the economic importance of the Middle East.

Chart 12, page 34.-- This chart shows world crude oil production and refining capacity. Our production is about 95 percent of our refining capacity, and we will soon have to increase our refining capacity substantially. This coming year, 1949, petroleum industry plans call for an increase of about 175,000 barrels per day in refining capacity in this country. The chart shows the preponderance of refining capacity over production in the European countries, and the necessity for exporting

crude from Venezuela and the Middle East, where there is not enough refining capacity to take care of their production. The surplus producing areas of the world are largely the Middle East and Venezuela. The United States is a producing-consuming area, almost in balance. Europe, despite the depredations of war, still has considerable refining capacity and requires substantial crude imports.

Chart 13, page 35.--I am taking considerably longer than I had intended, so will pass over this chart. If there is time after I have finished talking and anyone is interested in seeing the route taken by crude petroleum in going through the refinery and coming out as finished products, I will discuss it later. As a matter of fact this flow chart is largely self-explanatory.

Chart 14, page 36.--This chart shows the products obtained from a barrel of crude. The crosshatched quantities are from old type, straight run distillation before cracking processes were utilized. It must be realized that crudes vary greatly and the proportion of various products obtained from different crudes also vary greatly. The figures given are therefore approximate. Straight distillation gives about 30 percent of the crude as gasoline. Through cracking and reforming it is possible to get over 40 percent, 2 percent of which is high grade aviation gasoline. Straight distillation gave about 13 percent kerosene. We now get only 6 percent kerosene. In the distillates, or heating fuels, you originally got 7 percent and are now getting 17 percent. Of residuals--industrial furnace fuels and steam boiler fuels--we originally got some 49 percent and, as this is one of the principal materials now cracked to make more distillates and more motor gasoline, we get only 24 percent.

In 1919, when refineries were purely straight run distillation plants with no cracking, a refinery cost about $130 per barrel of daily through-put to build. To refine the crude costs about 25 cents per barrel. Twenty-five to thirty percent of the refined products was gasoline which had an average octane number of about 45. In 1929, to take an average year after the thermal cracking practices had become common, it cost about $230 per barrel per day of through-put to build a refinery and it cost about 30 cents per barrel to process the crude. It was possible to get up to 39 percent gasoline of about 60 octane number. With the present 1948-1949 plants, with catalytic cracking, a refinery costs about $1,300 per barrel per day, or ten times what the old straight run plants cost. It cost about 90 cents per barrel to process the crude and it is possible to obtain up to 45 percent gasoline with an octane number of around 70. This gives an indication as to the change in refinery practices--and the increased costs involved.

Chart 15, page 37.--This chart shows refinery yields. It indicates the flexibility with which a refinery may be operated. In 1945, during the war, it may be seen from the bottom of the middle column that we were producing roughly 12 percent aviation gasoline. That was abnormal and was achieved largely by robbing motor gasoline of some of its best components. You will undoubtedly remember that during the war the motor gasoline you purchased was often of low quality. It would probably knock when used in cars with a fairly high compression ratio engine. In the crosshatched distillate column, you will notice an increase in percentage of distillates from 13 percent in 1940 to almost 17 percent in 1947. This flexibility is extremely important because distillates have become increasingly important in commercial usage and they will be required in large quantities by the Military Services in case of a national emergency.

Chart 16, page 38.--This chart shows the past and anticipated petroleum demand, and it also shows the product breakdown for 1948.

Not only is it apparent that each year since 1946 there has been an increase in demand, but actually, the 1946 domestic demand was higher that the 1945 demand, which was the peak war period. This wholly unexpected requirement was caused in general by unprecedented industrial activity, and specifically by the increased number of cars that came into use (many people had had their cars up on blocks); by increased driving; through increased farm mechanization and increased use of equipment; and through change-over from coal to oil on railroads; for industrial use; for domestic heating; and also by the reconversion to oil by many large industrial concerns which had changed to coal to make more heavy fuel oil available to the war effort. The change-over from coal to oil was stimulated by the coal strikes and consequent uncertain coal availability. Everyone, including the government agencies involved as well as the petroleum industry, expected that, after the war year 1945, there would be at least a temporary reduction in petroleum demand in the United States. That it did not eventuate was as much of a surprise as was the industry's phenomenal ability to meet its unanticipated requirements with only one tight spot--during the unexpectedly severe winter of 1948.

Between 1941 and 1949, the number of licensed motor vehicles has increased from 33,500,000 to 42,000,000. There are 6,000,000 more cars now than there were in 1941 and 2,500,000 more trucks and buses. In 1941, 3.5 percent of the railroad locomotives were Diesel types. They are expected to account for approximately 25 percent of the total in 1949 when about 10,000 Diesel locomotives will be operated by the railroads. All the main trunk railroads will eventually be Dieselized.

Actually the conversion to Diesels reduces oil requirements--except where Diesels replace coal burners--as the Diesels are about four times as efficient as steam locomotives burning oil. In 1941, there were 2,[illegible]00,000 domestic oil burners in use; in 1949, they will total approximately 4,500,000. All of the foregoing shows the reason for the increase and indicates the trend.

I had planned to talk about the properties and uses of some of the various petroleum products at this point but will have to skip it until later as my time is rapidly running out. Suffice it to say that when I went with the petroleum industry in 1930 we were making about 100 products. In 1948, the petroleum industry made over 1,200 different useful products--fuels, lubricants, hydraulic fluids, special products, waxes, asphaltic materials, coke, carbon black, and many types of chemicals.

Chart 17, page 39.--The demand for petroleum products, world-wide, is indicated on this chart. It gives a clear indication of future petroleum requirements. From 1937 to 1949, world petroleum requirements have just about doubled. World petroleum requirements for 1949 are 85 percent over the wartime peak in 1945. The chart indicates the accelerated rate at which world requirements are increasing relative to United States requirements.

Chart 18, page 40.--This chart shows imports and exports. The tendency is definite. Imports are increasing. Exports are decreasing at a lower rate. In general, we import crude to make up our crude deficiency and export refined products. The chart shows that in 1947, for the first time since 1923, the United States became a net importer.

Chart 19, page 41.--This chart shows the sources of crude oil imported into the United States. In 1946, for the first time, we received some crude from the Middle East--and this has caused considerable controversy. Incidentally, the importation of Middle East crude into the United States is not what might be normally expected. Normally crude from the Middle East would take care of Africa, the Near East, the Middle East, the Far East and Europe; and our deficit would be made up from Venezuela, which is much closer to us and much farther from them. However, because of the present lack of development of refineries and other facilities in the Middle East, Venezuelan oil is serving much of the normal Middle East market.

Chart 20, page 42.--This chart is particularly interesting. It shows the changes in the relative use of the various sources of energy--water, coal, petroleum, natural gas--from 1900 to 1948. In 1900 about 7 percent of the total energy utilized in the United States was from natural gas and petroleum. By 1948 it had grown to 47 percent, and this

year will no doubt pass 50 percent. While this chart indicates the percentage changes in the sources of the total energy used during that period, it does not clarify one very important point: the fact that there has been a tremendous increase in our energy requirements during the past half century. In 1900, our total energy requirements were about 8,000 trillion BTU's and in 1948, 37,000 trillion--over 4.5 times greater. To represent true conditions, instead of percentages, the chart should be extended 4.5 times on the right-hand side. Then it would show not only the relative percentages of all different sources of energy, but the tremendous increase in energy requirements in the United States during the last five decades.

The most controversial question that we can get into is, "How long will these various sources of energy last?" There are about 175 trillion cubic feet of proved natural gas reserves; 6,000 cubic feet of natural gas has a heating value equivalent to about one barrel of oil. Considering the loss in conversion, the reserves of 175 trillion cubic feet are the equivalent of approximately 16 billion barrels of oil--or about two-thirds of the proved reserves of petroleum.

The United States maximum recoverable natural gas resources are put by authorities at a little over twice the proved reserves, or around 400 trillion cubic feet. We are now using about 2.7 trillion cubic feet of gas per year for household heating and industrial purposes. Another 1.6 trillion cubic feet per year are accounted for in carbon black manufacture, field use, and waste. Thus, our consumption, including loss, at the present time is about 4.3 trillion cubic feet per year.

Our domestic proved petroleum reserves, as previously indicated, are in the order of 25 billion barrels. Dr. Lewis G. Weeks, of the Standard Oil Company of New Jersey, one of the outstanding geologists of the country, estimates that the total recoverable reserves of crude petroleum in the United States were in the order of 110 billion barrels. We have already used 35 billion barrels, so that leaves about 75 billion barrels, or three times the actual proved reserves. That is a highly controversial figure, but it is the best estimate that the petroleum industry has to date.

After the natural gas reserves are depleted and all of the recoverable petroleum is used, it is possible by synthesis to develop additional sources of liquid fuels.

Liquid fuels may be obtained from shale oil. Most of the oil shale deposits in the United States are located in Colorado. There are probably 300 billion barrels of shale oil there, but much of it is not

economically extractable. Some of the ore is so very lean in oil that it would require a tremendous amount of mining to get a relatively small amount of shale oil. However, there are some 80 billion barrels of shale oil in Colorado, at a concentration of about 30 barrels per ton. This concentration will permit extraction at a reasonable cost.

Tar sands are found mostly in Canada. The amount of petroleum potentially present is enormous, but the readily workable tar sand deposits in Canada would be inadequate to supply our domestic requirements for one year. Until new methods of extraction are developed, these tar sands will remain relatively unimportant.

Coal is the principal source from which we might expect to get synthetic liquid fuels in the future. There are about 5,200 billion tons of coal now proved. We are using about .6 billion tons of coal a year. Since half a ton of coal is equivalent to a barrel of oil, it would take about 1.3 billion tons a year more to take care of present requirements for oil. Thus we would have a total requirement of, say, 2 billion tons of coal per year. This would indicate that at the present rate of consumption we have enough coal, theoretically, for about 1,600 years. However, much of that coal is not extractable. Much of it cannot be economically handled. Our requirements are increasing rapidly. The most pessimistic figure given by the experts is that we have only enough coal for 200 more years. From this you can draw the conclusion that we have coal for somewhere between 200 and 1,600 years.

Chart 21, page 48.--I will deal with this chart very briefly. It shows schematically the methods used in synthesizing liquid fuel from natural gas, from coal, and from shale oil. To make liquid fuels from natural gas, the gas is burned with a deficiency of oxygen to synthesis gas--largely carbon monoxide and hydrogen. The synthesis gas is then treated over a finely divided iron type catalyst under heat and pressure and produces about 90 percent very high-grade motor gasoline and about 10 percent fuel oil. From the water phase it is possible to extract the oxygenated compounds--alcohols, ketones, and other chemicals.

Liquid fuel from coal is obtained in much the same manner. Coal can either be mined and coked, or may be burned incompletely in place. In either case, the coal gas which is formed is treated with steam and an insufficiency of oxygen to make synthesis gas. Then through the Fischer-Tropsch process, it is converted into aviation gasoline, motor gasoline, and fuel oil. The refinery shown represents the hydrogenation type. This method of synthesis was used very effectively in Germany during the war. More efficient methods have now been devised. Extensive research is being conducted by the petroleum industry to the end of developing more efficient and economical methods of synthesizing liquid fuel from coal.

from other materials, our natural petroleum resources will be inadequate to meet our total requirements in a very short time--certainly less than 10 years.

If we say, "How long will we have indigenous liquid fuels available in this country?", the problem takes on a different complexion. If we accept the most optimistic viewpoint, I think we can say that liquid fuels from gas and petroleum will meet our requirements for a decade; liquid fuels from shale oil will last at the most a century; and liquid fuels from coal may last a millenium. Pessimistically, or conservatively, it appears that, with the anticipated increased usage, the total liquid fuel resources of this country may be used up in as little as 250 years.

Some people think that when the liquid fuel resources are used up, we will merely convert to atomic energy. However, the sources of atomic energy are not inexhaustible. Actually they are substantially less than our resources of liquid fuels. We are presently mining our uranium potential at something over one-thirtieth of the total per year, so at the present rate, we will completely deplete our uranium reserves in 30 years. The rate at which the energy derivable is used is another matter but it is obvious that it won't last long if used in dropped atom bombs. It is estimated by competent authorities that we have less than one-tenth of the world's uranium reserves. Petroleum costs one cent a pound and uranium $5 a pound. There are roughly 100,000 times as many pounds of petroleum as there are of uranium in the United States. All of the above indicates that atomic energy is not the solution to our problem.

The fundamental problem with which we are faced is that our unrenewable sources of energy are rapidly running out. We must use more of the continuous sources of energy. We must use more water power, more power derived from the sun, more power from the wind, more power from tides, from temperature differentials, and so forth. The increased use of those continuous sources will tremendously increase the life availability of our liquid fuels. It is obvious that our liquid fuels are vital to our economy and essential to the waging of war as we know it today.

The advantages of adequate national liquid fuel resources are obvious. To be dependent upon outside sources would be an intolerable military handicap. It is very desirable that we be able to consider the entire Western Hemisphere as one source. If we can do that, we have materially increased liquid fuel availability and, as a result, our operational flexibility should war be thrust upon us. There can be no question that Germany and Japan were more easily defeated when their

To obtain shale oil it is necessary to mine the shale, crush it, and retort it. Having extracted the oil from the shale, it is then converted into desired liquid products by various refining processes. Unfortunately, shale oil is high in sulphur and nitrogen. With conventional refining methods, it gives very little motor gasoline and a poor grade of fuel oil. It converts readily to bunker fuel, which at the present time, and in Colorado, is not of great interest. However, various oil companies and the Bureau of Mines are doing a great deal of work to devise more economical means of mining shale, more economical and efficient means of retorting it, and more flexible means of refining it.

To sum up and conclude this talk, I would like to bring out the following points: During World War II the United States, with at that time roughly one-third of the world's proved reserves, furnished two-thirds of the world's requirements and substantially depleted her resources. Now it is probable that the United States has less than a quarter of the oil in the world. I say that despite the fact that our proved resources are now rated at something over 30 percent, because we have explored so much more aggressively and thoroughly than has been the case in the Middle East. We are still using more than all of the rest of the world put together.

The prodigality with which we use oil in this country is indicated by the fact that the per capita consumption of petroleum in the United States is 14 barrels per year. In South America, it is 1.5 barrels per year; in western Europe and in England, about 2 barrels per year; in the Axis countries, Italy and Germany, slightly less than half a barrel at present; in the Far East, something less than one-tenth of a barrel. When considering the world as a whole, each individual on the average uses 1.4 barrels per year. In America, we use 14 barrels per capita per year--or ten times as much oil as the average citizen of the world.

I would like to point out again that the substantial oil findings which occurred in 1948 and the latter part of 1947 were largely due to the high price of crude and petroleum products which stimulated exploration and production and made marginal supplies economically available.

We come again to the controversial question of how long will the petroleum in the United States last. Our oil reserves can be recovered only over a period of many years and at gradually declining rates. It is therefore impossible to arrive at correct conclusions as to the life of our reserves by dividing the reserves by the current or even the anticipated annual requirements. I think, however, we can pretty safely say that our petroleum reserves will be seriously depleted in 50 years, and when consideration is given to continually increasing requirements and our dwindling resources, that unless we import crude or synthesize

supplies of liquid fuels and their refining capacity were destroyed and their mobility thereby restricted. I am sure that today's international unrest, aside from ideologies, is due in no small part to a desire on the part of the various nations involved to control the world reserves of crude petroleum, particularly in the Middle East.

So, in conclusion, I would say that we must conserve our natural resources. We must avoid waste. We must import crude petroleum in increasing amounts in order to make up our deficiency. We must be ready soon to synthesize liquid fuels from shale oil and from coal. I am not talking as a petroleum man now. I have my petroleum hat off entirely. I am talking as a citizen and taxpayer about national welfare and security. And finally, we must start utilizing immediately and increasingly the continuous sources of energy in order to conserve our diminishing supply of expendable energy. Thank you very much.

QUESTION: Would you care to comment a little further about the present condition of refinery capacity? I have basically in mind the capacity to meet anticipated requirements, the physical condition of the refineries. We have been told that refineries have been operated above capacity and under pressure during the period of the war and as a result maintenance ran down. You have indicated that the requirements have continued so I assume we still have too little capacity. Would you comment briefly on that?

GENERAL DOOLITTLE: That is correct. We are now just comfortable on required refinery capacity. The various oil companies are putting in additional refinery capacity in order to meet the requirements of the future. They did, during the war, run their refineries at substantially higher output than had been customary before. This didn't cause undue maintenance but it did necessitate minor changes in the refineries. Now almost all of the industry's refineries are running at that increased output under absolutely normal conditions with only minor alterations which necessitated relatively small capital investment. It is just another case of one never knowing what he can do until he has to.

QUESTION: How long were the oil wells in the East Indies out of production?

GENERAL DOOLITTLE: In the East Indies destruction was probably carried out to a greater degree than anywhere else. I can't give you the exact figure as to how long production was shut down. I do know that under some conditions the oil wells were destroyed completely and had to be redrilled. Under other conditions the demolition people were a little slow and those wells were unaffected or not badly damaged. Probably the best answer to your question is that by proper demolition

an oil well can be put out of commission so permanently that it is better to start over again and drill a new one. As you saw on the chart, the East Indies has not yet gotten back to its 1938 production.

QUESTION: I wonder if you will put your oil man's hat on and look at the Middle East oil being imported. How is it affecting this country's oil industry and how do you expect that it may continue to affect it?

GENERAL DOOLITTLE: The shipment of Middle East oil to this country has caused a great deal of controversy, particularly on the part of the independents and the individuals who own oil properties here and who feel that the value of their oil is being reduced as a result of the importation of foreign oil. That is not only true of the Middle East oil, but of oil from Venezuela as well. Oil from Venezuela has generally been shipped into east coast ports, and occasionally into Gulf Coast ports. From the point of view of certain individuals and companies there will be inconvenience and possibly even some loss suffered as a result of the importation of oil from either Venezuela or the Middle East, but from the point of view of national welfare in conserving our national resources and insuring our military mobility it is extremely desirable, as a matter of fact essential, that we start increasing our imports. Otherwise, we are going to run out of oil and we will become a "have-not" nation. The Middle East will long be an important source of oil.

QUESTION: You pointed out that kerosene has certain advantages over gasoline for jet engines. Will producers produce more kerosene?

GENERAL DOOLITTLE: There are three important aspects to the jet fuel problem. The first aspect is availability. The use of kerosene alone restricts availability. If a wide distillation range fuel is used, availability is increased. The distillation range of such a fuel covers the gasoline, kerosene and fuel oil range. It contains light, medium and heavy fractions. I will show you a chart that will indicate just how much availability can be increased by widening the distillation range. (The chart indicated that availability may be increased over 6 times by simply widening boiling range and up to 9 times by including cracked products.)

The second requirement is maximum BTU's per gallon. This means a heavy high boiling point fuel. The ultra high-speed airplanes of the future are going to be volume-limited rather than weight-limited. The number of gallons of fuel that is possible to store or carry in their narrow fuselages and thin wings will be the range-limiting factor of

these planes. Consequently, the heaviest possible fuel is required in order to get the maximum number of BTU's into a given volume.

The third requirement calls for easy starting, particularly under conditions of extreme cold, for restartability at high altitudes, for clean ready burning and for flow and pumpability at low temperatures. This indicates a light fuel. There are definite indications that the heavier fuels do not incline to burn as well and as cleanly as lighter fuels. Furthermore, aromatics and olefins, which are heavier than corresponding paraffins, do not ordinarily burn as readily. The former tend to smoke and the latter to form carbon. It will require a considerable improvement in engine design in order to be able to burn the heavier fuels. England is a little ahead of us in this respect. The English started a few years earlier and we have not yet entirely caught up.

A compromise between availability, range and engine performance is indicated. My own opinion is that we will go to heavier fuels as soon as availability and engine design will permit. During the war, range was always a major problem. The enemy cunningly moved back, if he could, just out of range. In any future war, aircraft range will be even more important. Consequently, a heavy fuel will be required. The engine manufacturer must design for it and the fuel manufacturer must so arrange his manufacturing processes as to provide it.

QUESTION: How soon will you produce gasoline that will operate in these new automobile engines, these rocket engines, with the 12 to 1 compression ratio? We understand they don't have the fuels at the present time.

GENERAL DOOLITTLE: The answer is that the petroleum industry will produce it as soon as it is required. Last year General Motors would have liked to come out with a very high compression engine. They didn't because there was an over-all world shortage of petroleum products. That shortage is just being corrected now, and I would guess that very shortly it will be possible to take a cut off the cylinder head, increase the compression ratio, and get more efficiency out of their newest engines.

There are two ways to accommodate these very high compression ratio engines. One is through the use of a special high octane number fuel, and the other is through the use of standard fuel and an additive. This additive may be injected into the induction system in much the same manner that water and methanol are employed in order to permit more power to be drawn from aviation engines. Even in stop and go driving, with a 12 to 1 compression ratio engine, the super fuel is required for only a very small part of the total driving time. This system has actually

been tried out in Columbus, Ohio, and has worked very satisfactorily. Th additive is water, methyl alcohol, and tetraethyl lead. The so-called "Vitometer" is hooked into the induction system in such a way as to meter the proper amount of the antidetonating material into the carburetor when the throttle is depressed and the engine is operating at a high M.E.P. I personally like this system which is economical and mechanically simple. However, the petroleum industry can and will, within the limitations of practicality, make higher octane number motor fuels available as they are required. This must be done in such a manner as not to interfere with the availability of fuels for the Militar Services, particularly aviation gasoline. Furthermore, the economics of the new fuel must be such as to permit advantages in power and economy of operation commensurate with increased cost.

QUESTION: You spoke about the percentage of dry holes. Do they include exploitation wells, as you call them?

GENERAL DOOLITTLE: Chart 7 showing the ratio of dry holes was for all wells, exploration as well as exploitation. In 1948 the dry holes drilled represented about 85 percent of the total wells drilled. The wildcat or exploration wells were something over 80 percent dry holes.

QUESTION: That is the chart I am talking about. Was that a cumulative chart or year by year?

GENERAL DOOLITTLE: Year by year. The vertical distance on the chart is for each year.

QUESTION: I was a little curious because it would seem you gave part of the explanation. I am still a little puzzled at the fact that, with all the advances we have made in avoiding dry holes, we continually get higher percentages, which indicates we are getting worse all the time.

GENERAL DOOLITTLE: No, it indicates that, despite our increased ability and increased technical knowledge, we are running out of oil and it is becoming increasingly hard to find. Less than 10 years ago it used to cost about 15 cents a barrel to explore for oil. Now if we can find oil for a half dollar a barrel we are delighted. We are spending over three times as much to find it, and we are finding less.

QUESTION: It looks as if the conversion to Diesel helps in the conservation of petroleum.

GENERAL DOOLITTLE: It does very definitely.

QUESTION: Do you see any possibility of that happening?

GENERAL DOOLITTLE: When you convert from steam engines burning fuel oil to a Diesel engine you substantially increase the availability of petroleum because the Diesel engine is roughly four times as efficient as the steam engine. But when the conversion is from a coal burner to either an oil burner or a Diesel, you lose yards on the play.

QUESTION: What I am thinking of is the possibility of converting motor cars to Diesels. Do you see any possibility of that?

GENERAL DOOLITTLE: The aviation industry is ahead of the motor car manufacturers in obtaining maximum engine efficiency. The principal advantage of the Diesel engine lies in its low specific fuel consumption. Through the use of higher compressor ratios and 100-octane fuels it is possible to achieve about the same fuel consumption as in the Diesel. Germany at the beginning of the war was ahead of the rest of the world in the development and use of Diesel aircraft engines. When the Germans got in the war, they promptly abandoned their Diesels and used only conventional Otto-cycle engines. From the aviation point of view the Diesel engine is a dead duck. From the automotive point of view it still offers some advantages, but the advantages offered are not so much in the increased efficiency as in the fact that it is still possible to buy Diesel fuel for somewhat less than is paid for gasoline. A few years back Diesel oil was much cheaper than gasoline. As requirements for that type of fuel became greater, the value increased and the differential between Diesel fuel and gasoline became smaller. The principal advantages of the Diesel engine are in long-haul trucking operations. The Diesel engine is definitely not so flexible as the Otto-cycle engine and, therefore, not so readily adaptable to passenger car operations.

QUESTION: General, there has been a considerable percentage of oil in wells that is not recoverable. What progress is being made in research in secondary recovery methods?

GENERAL DOOLITTLE: Tremendous progress. The east Texas field, for instance, which is still one of the most prolific producers, has been tremendously benefited by water repressuring. I have a chart which shows this but unfortunately I didn't bring it. I think, however, that the picture of the anticline of chart 2 will permit me to illustrate the methods used.

This is the classical way in which you find petroleum in an anticlinal structure. The gas is dispersed on top of the oil. Next the oil, last the water. If the water pressure head is higher than the ground level over the top of the anticline, the water will exert enough pressure to force the oil out and there will be a free flow of oil. Alternatively if the gas pressure is sufficiently great, it will force the oil out.

Eventually as the pressure drops below a certain point the oil will no longer flow. There are then three principal ways to get it out. One is to pump it. If there is still enough pressure to force the oil to seep through the sand into the well, it may be pumped out with the typical old bucket-type pump like Grandma used for pumping water. Another way is to drill a well offside and force water into it. The force of that water will in some cases repressure the original well and force the oil up. Alternatively, gas may be introduced above the oil level and the gas pressure may force the oil out. There are four general methods used in the recovery of oil: (1) natural free flow due to normal water and gas pressure; (2) pumping; (3) reintroduction of water; and (4) reintroduction of gas.

The west Texas fields originally produced at about the same level as in east Texas. After depleting this level they drilled deeper and discovered a new field under the old one. The original wells in west Texas produced at around three to four thousand feet. Repressuring and deeper drilling has caused repeated upward revisions of original reserve estimates.

QUESTION: I would like some idea of the percentage gains, if you have any. About what percentage is being recovered at the present time?

GENERAL DOOLITTLE: It varies. In some cases no gain can be achieved through repressuring. In other cases a field may run dry and then through repressuring the secondary recovery may be as much as was gotten out in the first place. It is impossible to give an accurate average percentage gain through repressuring, because in one case you may get none and in another recover more than was extracted before.

COLONEL HOEFFER: General, on behalf of the College and guests I thank you for a very instructive talk on petroleum. I am sure we have gained some very valuable information from it.

GENERAL DOOLITTLE: Thank you very much for your courtesy.

(12 April 1949--750)S.

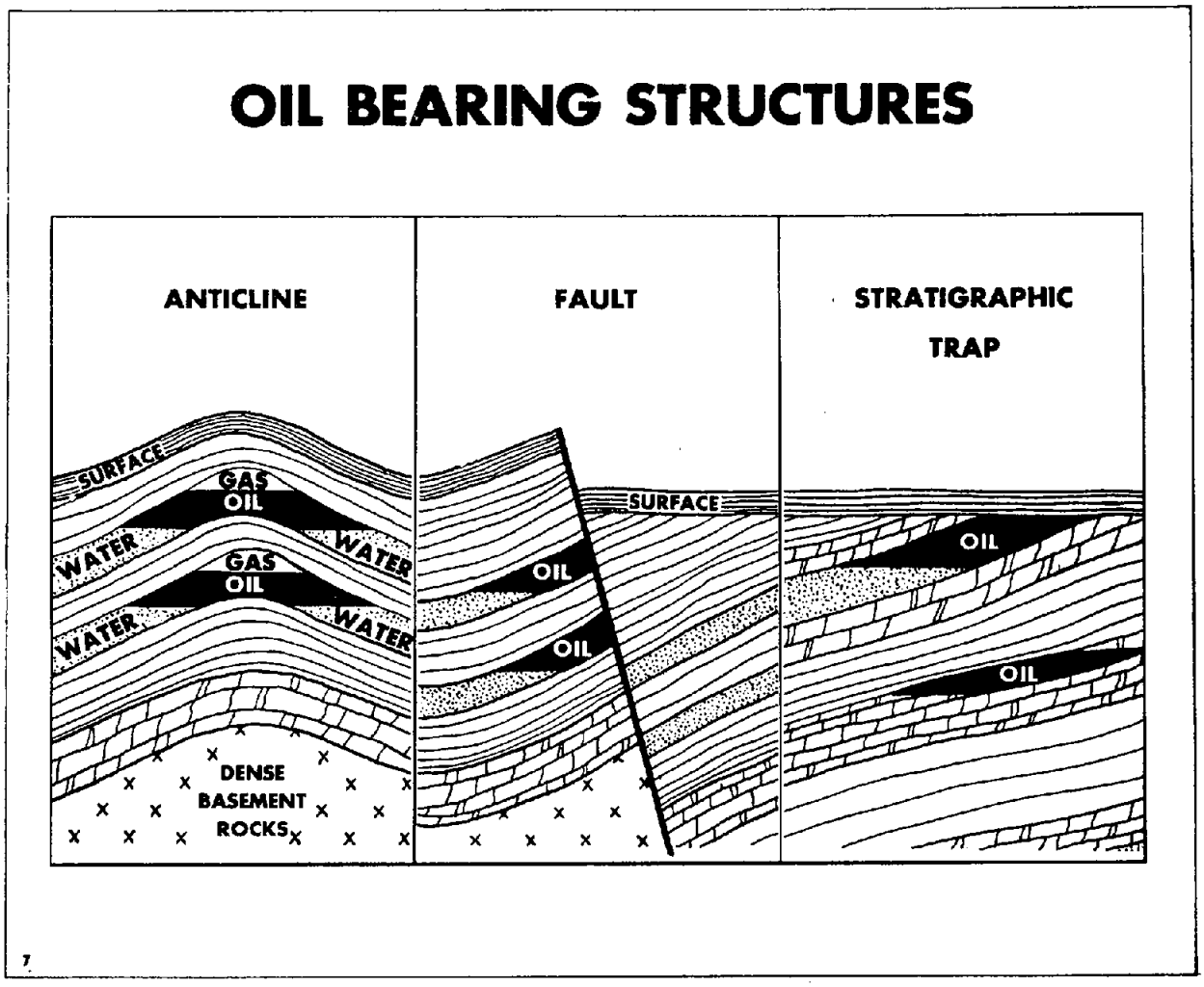
Chart 1

THE PETROLEUM INDUSTRY

EXPLORATION
PRODUCTION
MANUFACTURING
TRANSPORTATION
MARKETING

RESEARCH
ADMINISTRATION

Chart 2


OIL BEARING STRUCTURES
ANTICLINE
FAULT
STRATIGRAPHIC TRAP
SURFACE
GAS
OIL
WATER
WATER
GAS
OIL
WATER
WATER
DENSE BASEMENT ROCKS
SURFACE
OIL
OIL
OIL
OIL

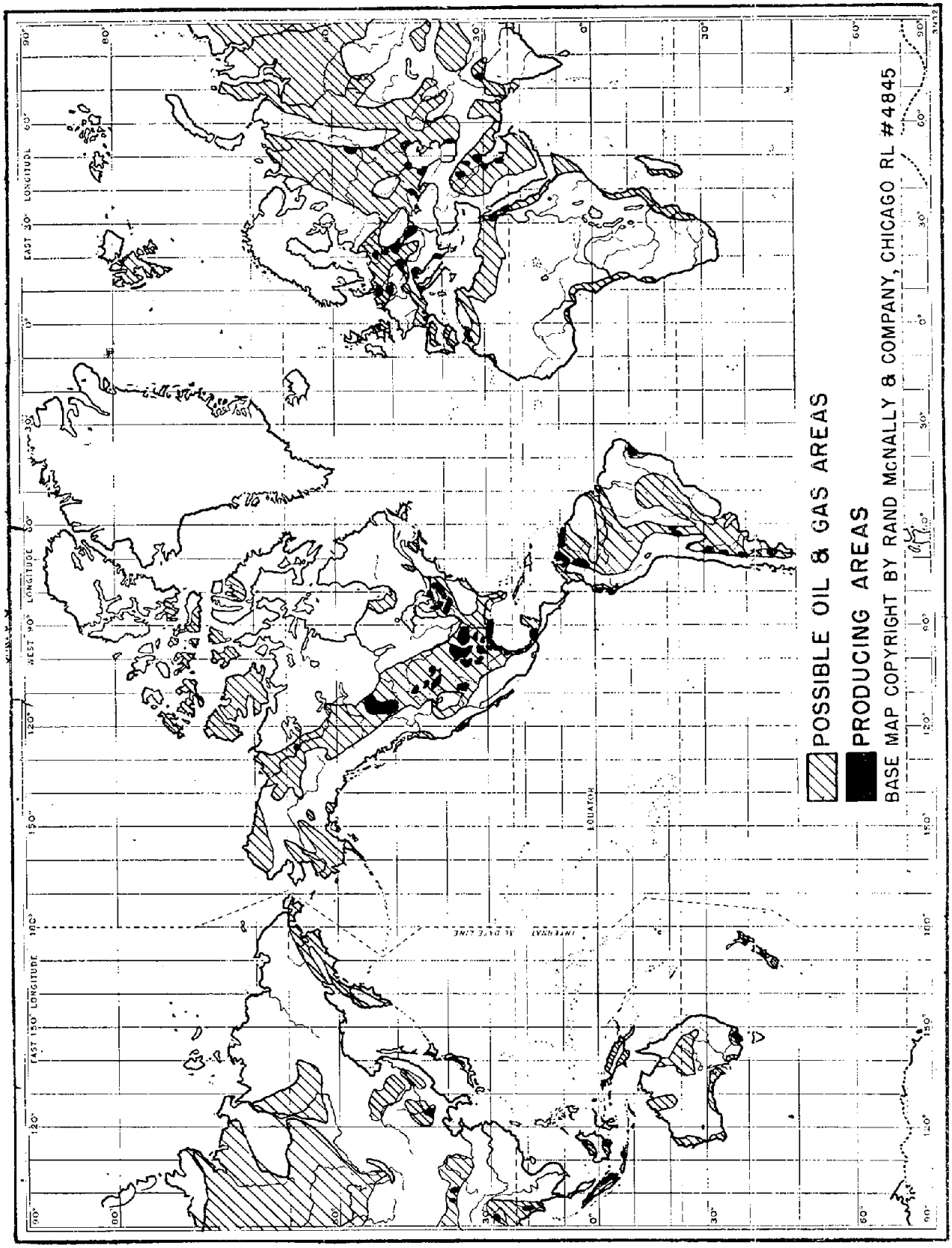

POSSIBLE OIL & GAS AREAS
PRODUCING AREAS
BASE MAP COPYRIGHT BY RAND McNALLY & COMPANY, CHICAGO RL #4845
EAST 150° LONGITUDE
WEST 90° LONGITUDE
EAST 30° LONGITUDE
EQUATOR
INTERNATIONAL DATE LINE

Chart 4

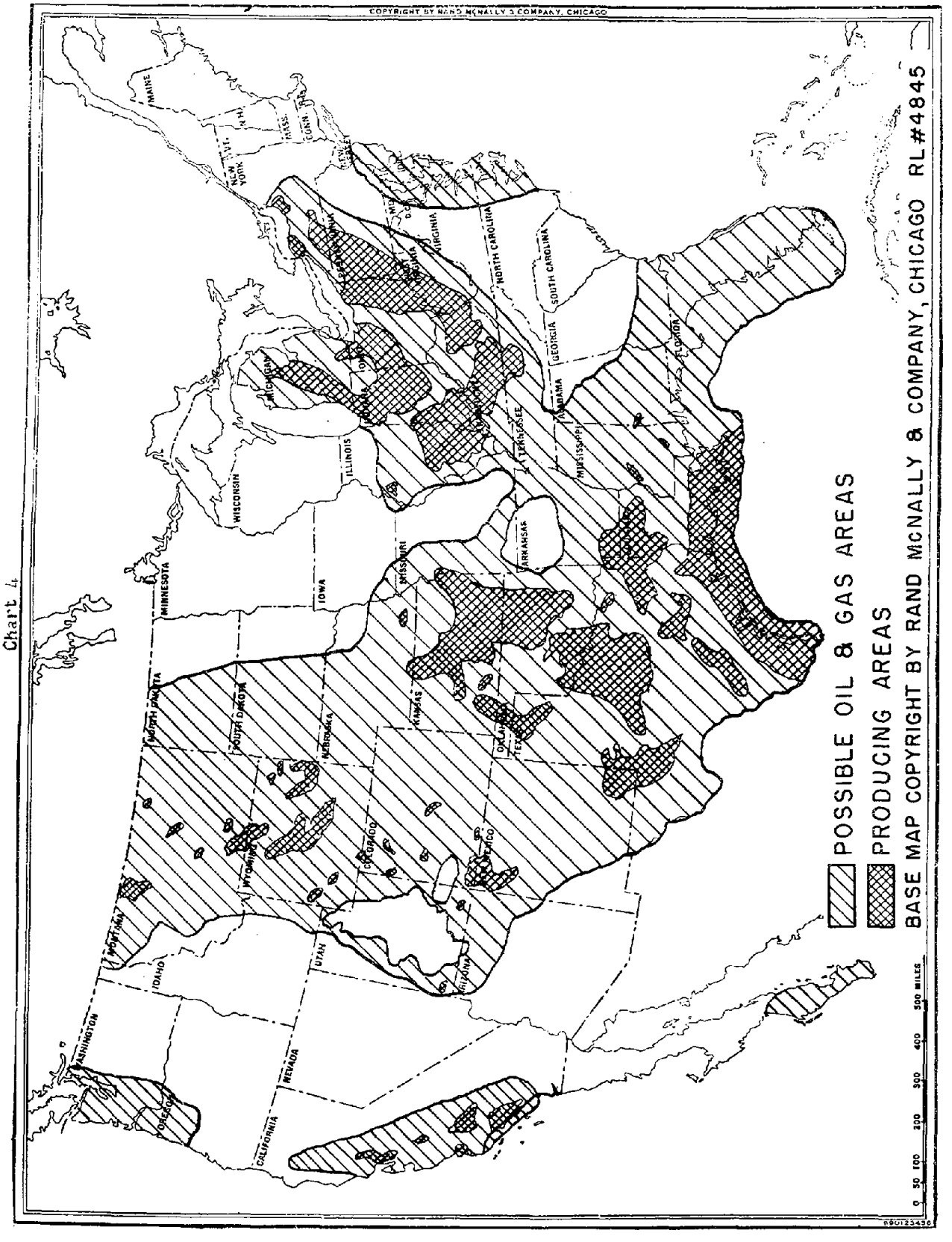

COPYRIGHT BY RAND McNALLY & COMPANY, CHICAGO
POSSIBLE OIL & GAS AREAS
PRODUCING AREAS
BASE MAP COPYRIGHT BY RAND McNALLY & COMPANY, CHICAGO RL#4845
0 50 100 200 300 400 500 MILES
MAINE
N.H.
VT.
NEW YORK
MASS.
CONN.
R.I.
PENNSYLVANIA
NEW JERSEY
DELAWARE
MARYLAND
D.C.
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
TENNESSEE
KENTUCKY
OHIO
INDIANA
ILLINOIS
MICHIGAN
WISCONSIN
IOWA
MISSOURI
ARKANSAS
LOUISIANA
TEXAS
OKLAHOMA
KANSAS
NEBRASKA
SOUTH DAKOTA
NORTH DAKOTA
MINNESOTA
COLORADO
NEW MEXICO
WYOMING
MONTANA
IDAHO
UTAH
ARIZONA
NEVADA
CALIFORNIA
OREGON
WASHINGTON
R9U123456

Chart 5

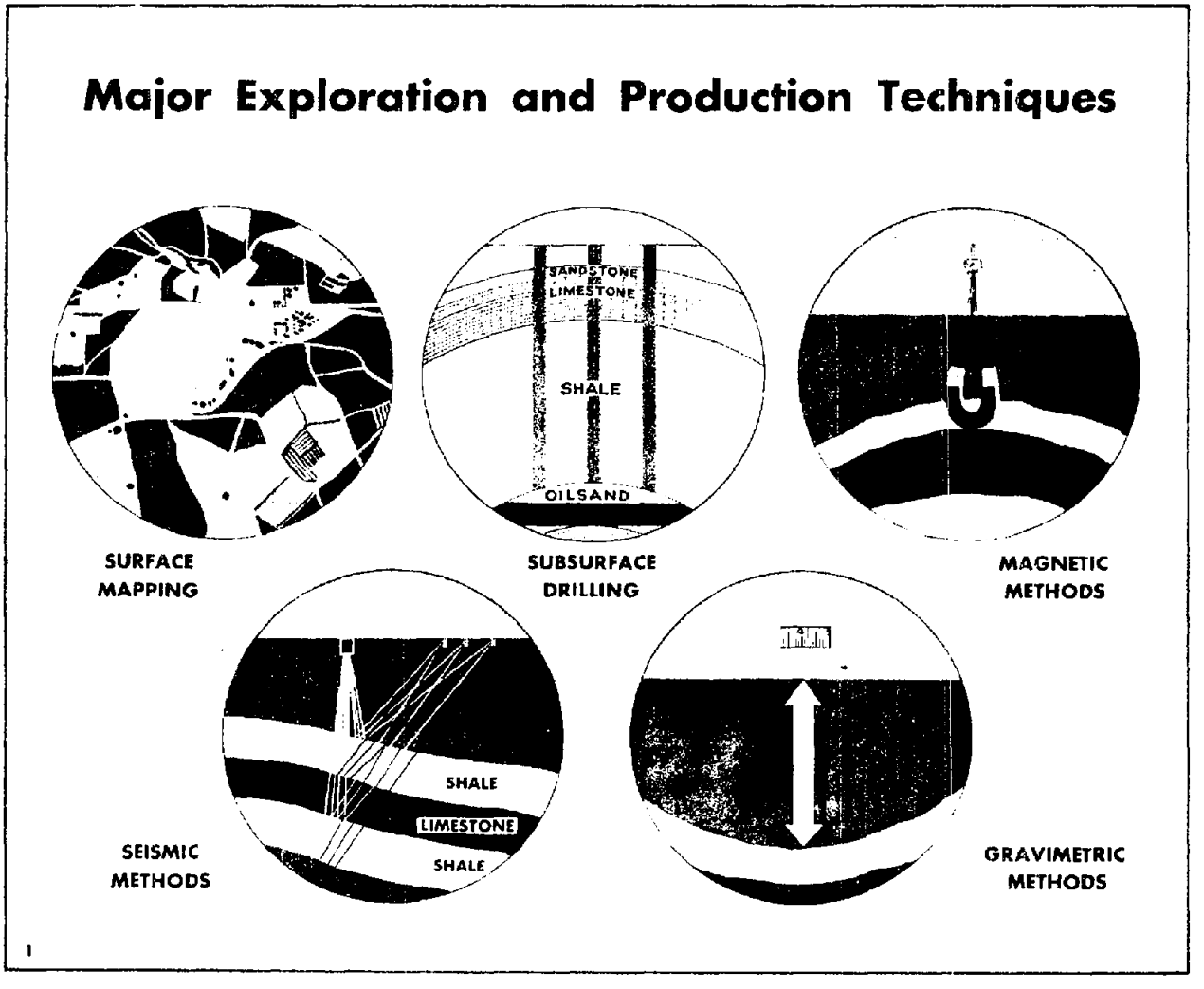

Major Exploration and Production Techniques
SANDSTONE
LIMESTONE
SHALE
OILSAND
SURFACE MAPPING
SUBSURFACE DRILLING
MAGNETIC METHODS
SHALE
LIMESTONE
SHALE
SEISMIC METHODS
GRAVIMETRIC METHODS

Chart 6

DRILLING COSTS

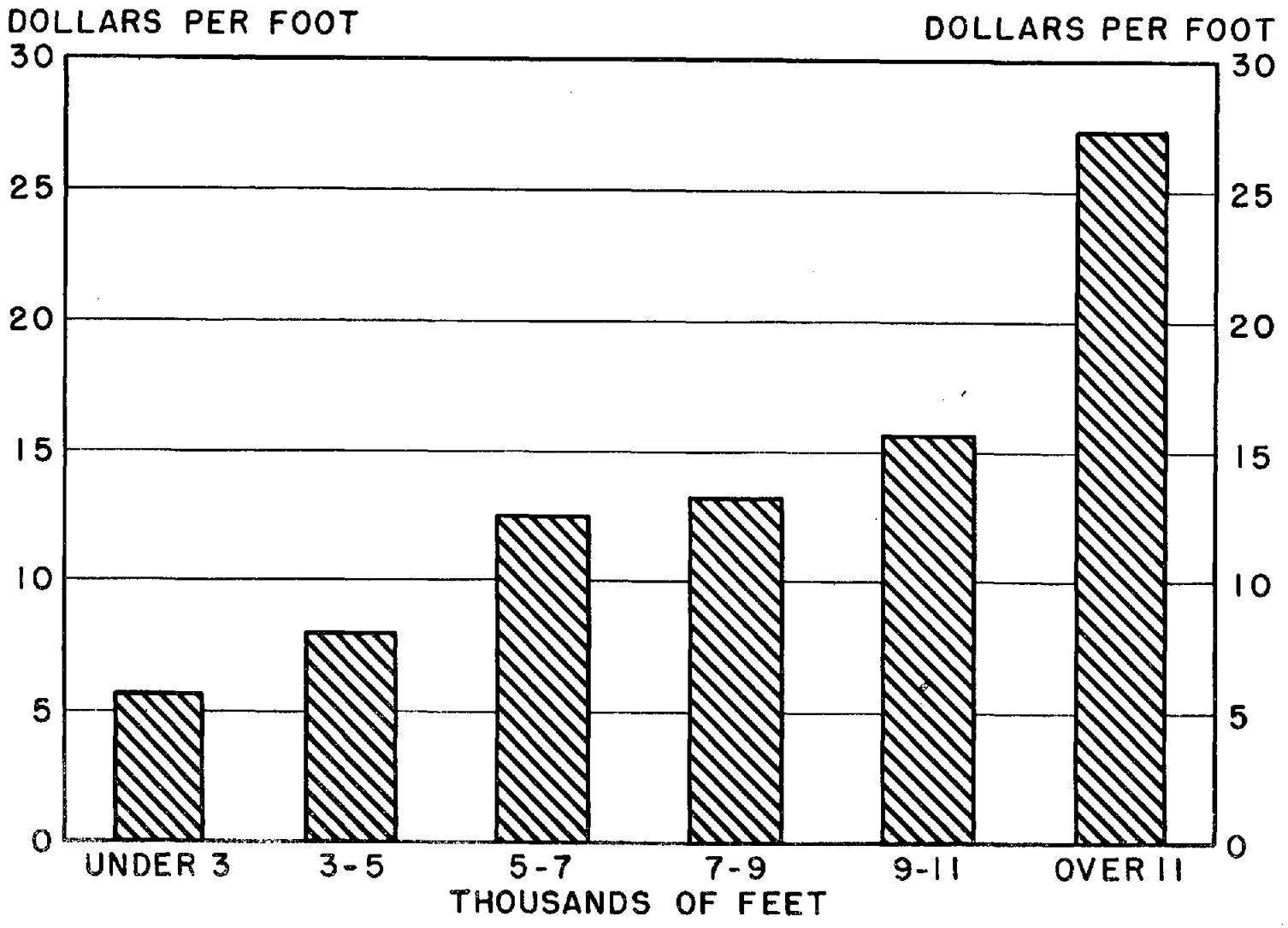


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Chart 7

PER CENT OF DRY HOLES TO TOTAL WELLS DRILLED
DOMESTIC U.S. PETROLEUM INDUSTRY

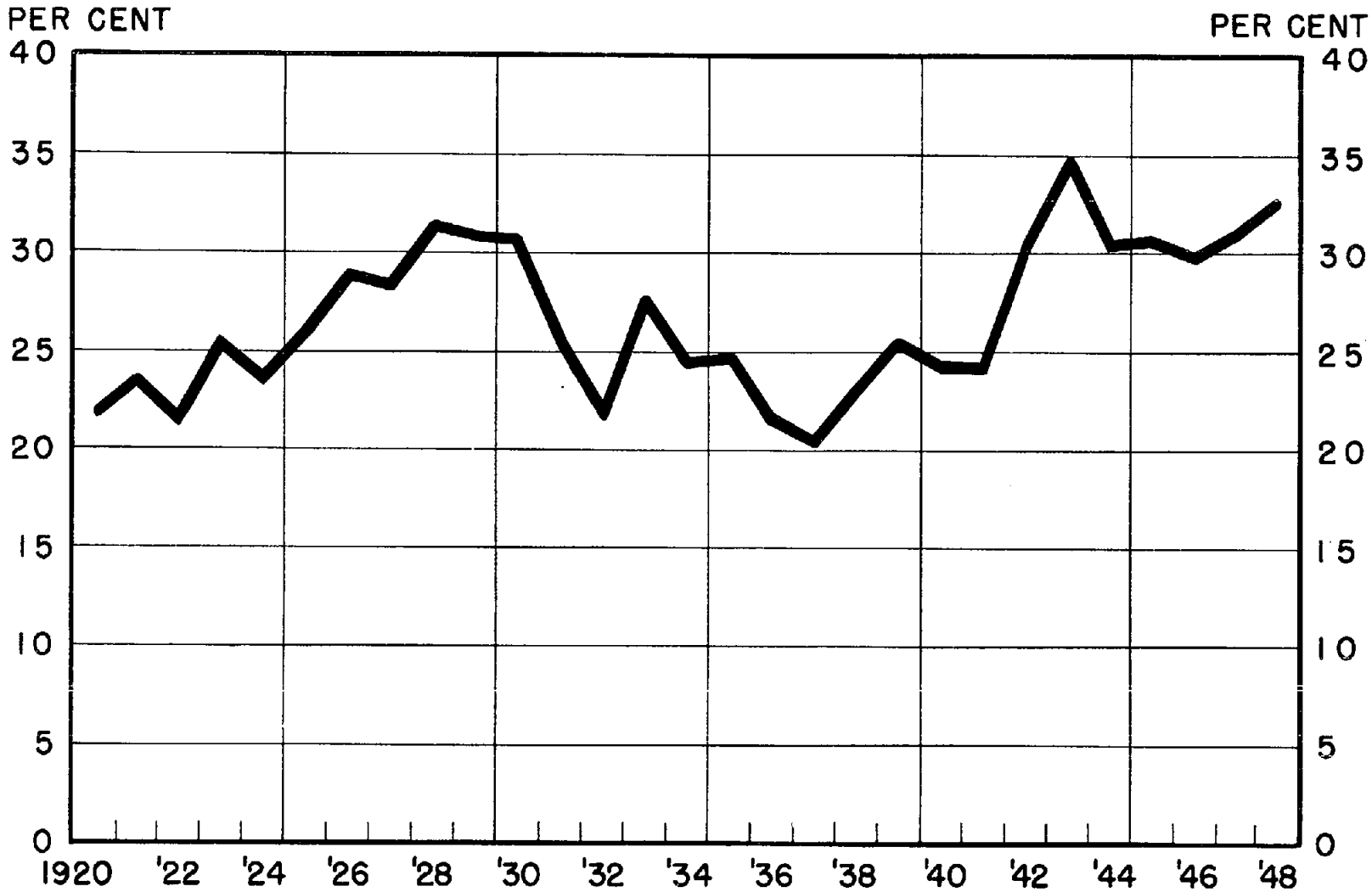

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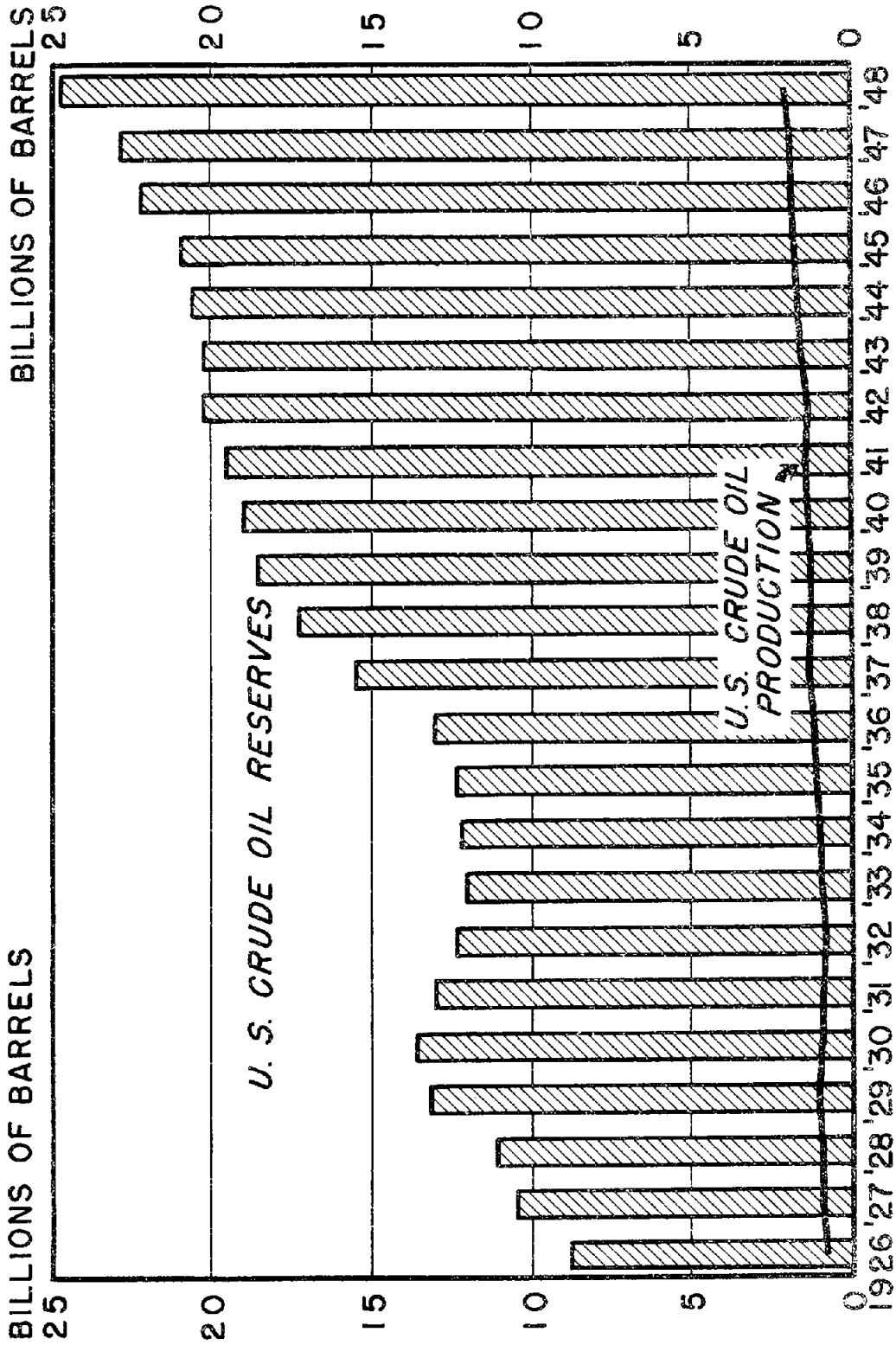
Chart 8

U. S. CRUDE OIL RESERVES



Source: 1926-1947 — A.P.I.
1948 — OIL and GAS JOURNAL

Chart 9

CRUDE-OIL RESERVES 1948

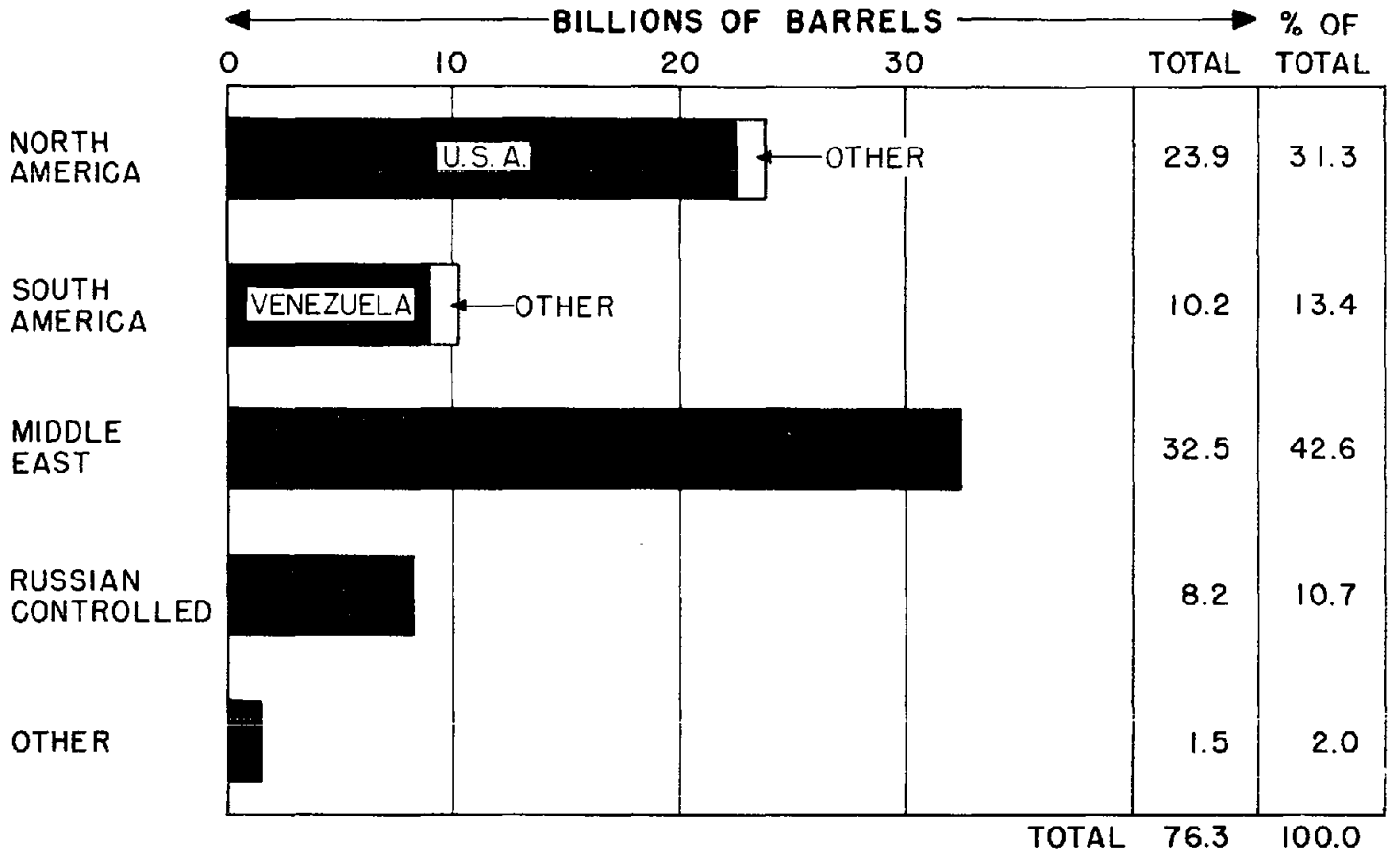


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Chart 10

U.S. CRUDE OIL PRODUCTION

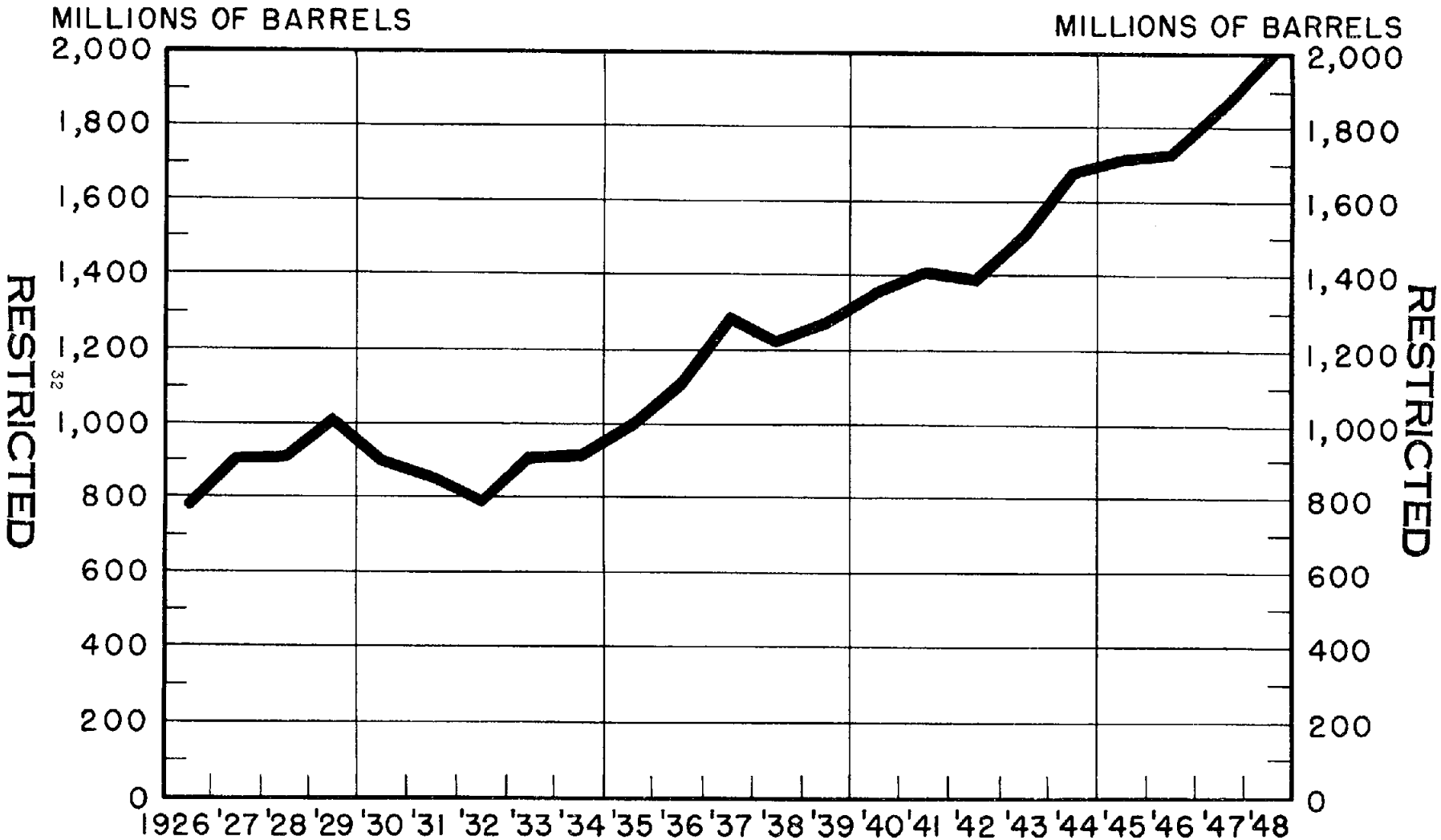

Chart 11

CRUDE-OIL PRODUCTION 1948

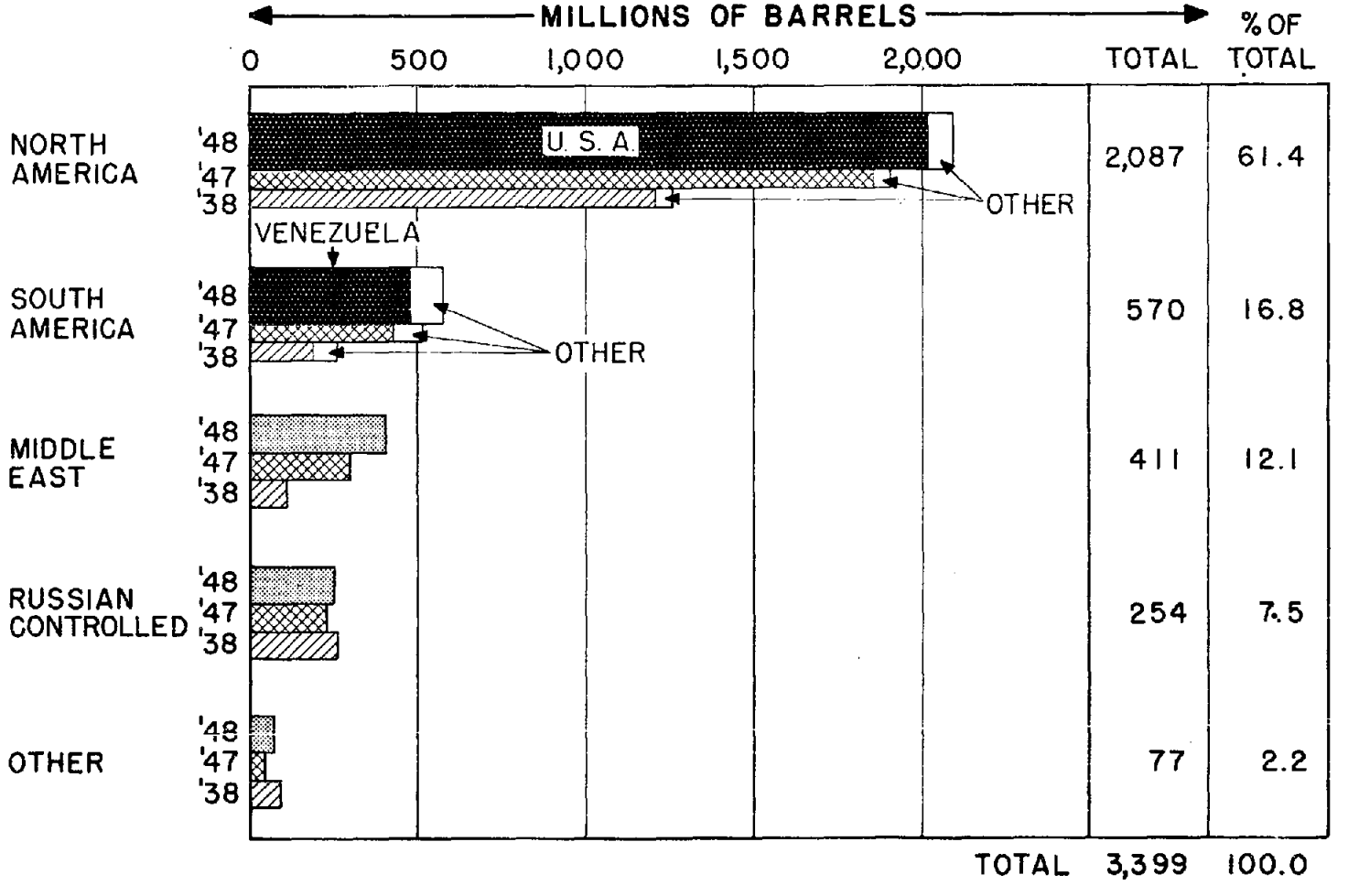

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Chart 12

CRUDE OIL PRODUCTION & REFINING CAPACITY

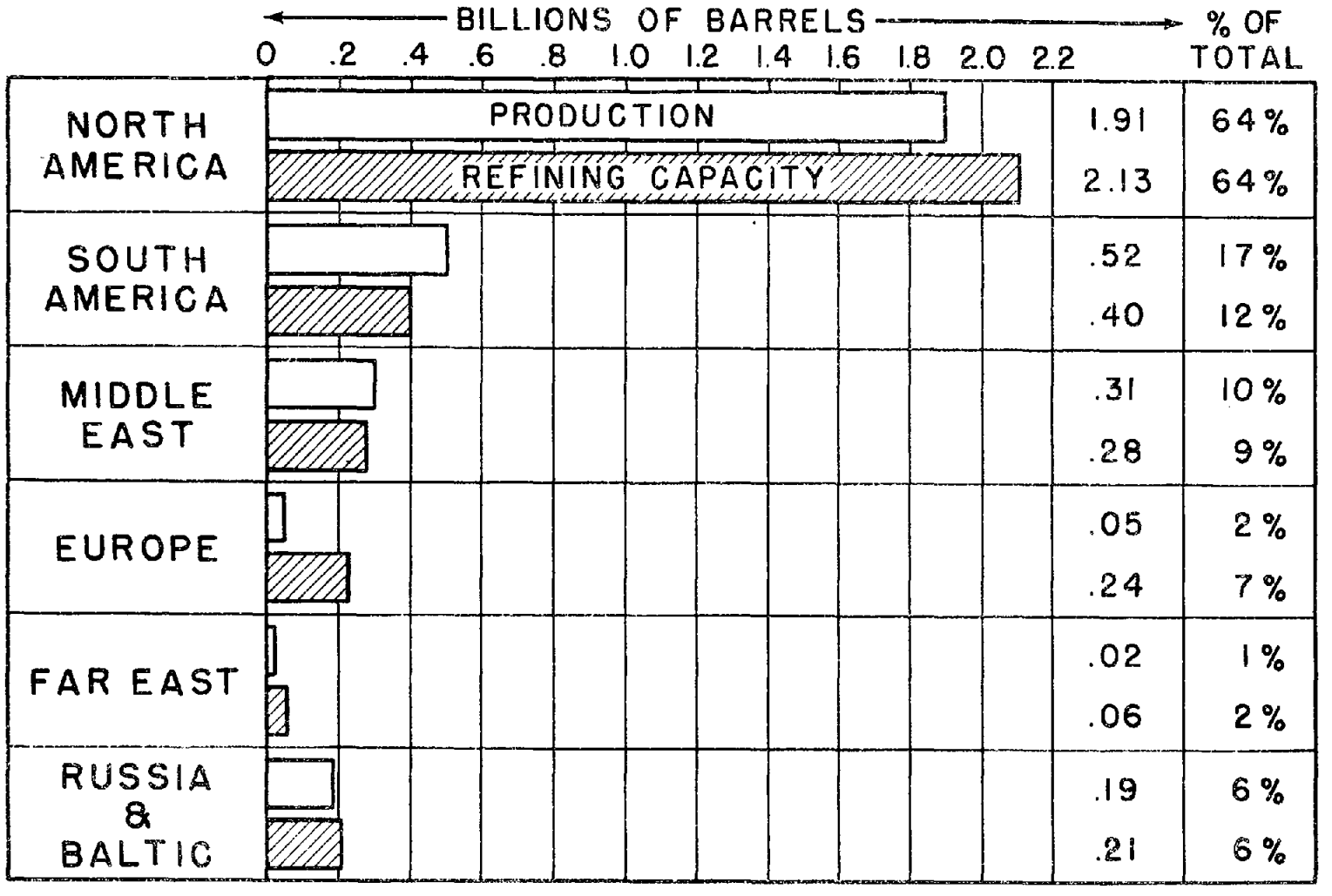

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Chart 13

Typical FLOW CHART *tracing* Crude Oil *from well to finished products*

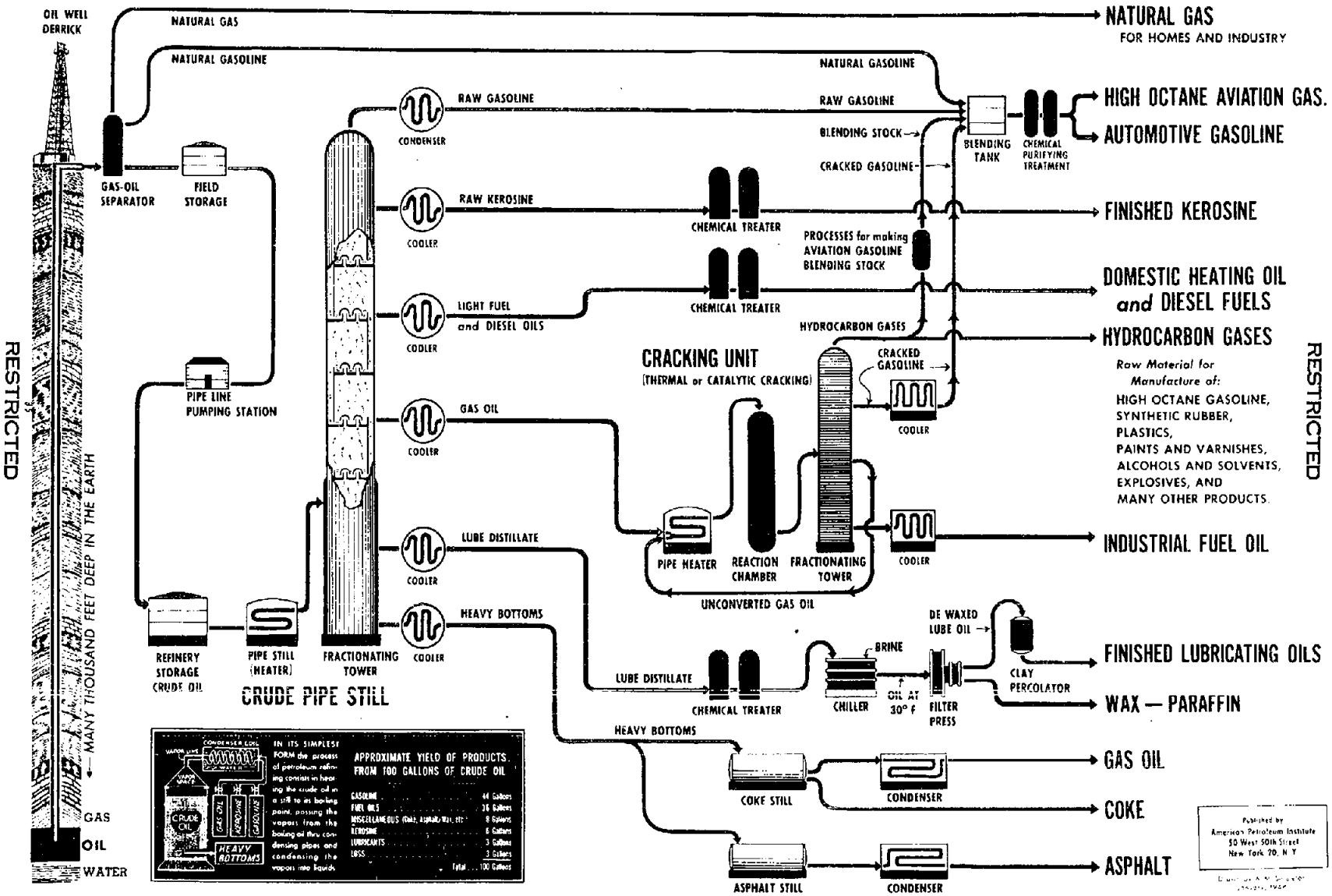

Chart 14

PRODUCTS FROM A BARREL OF CRUDE

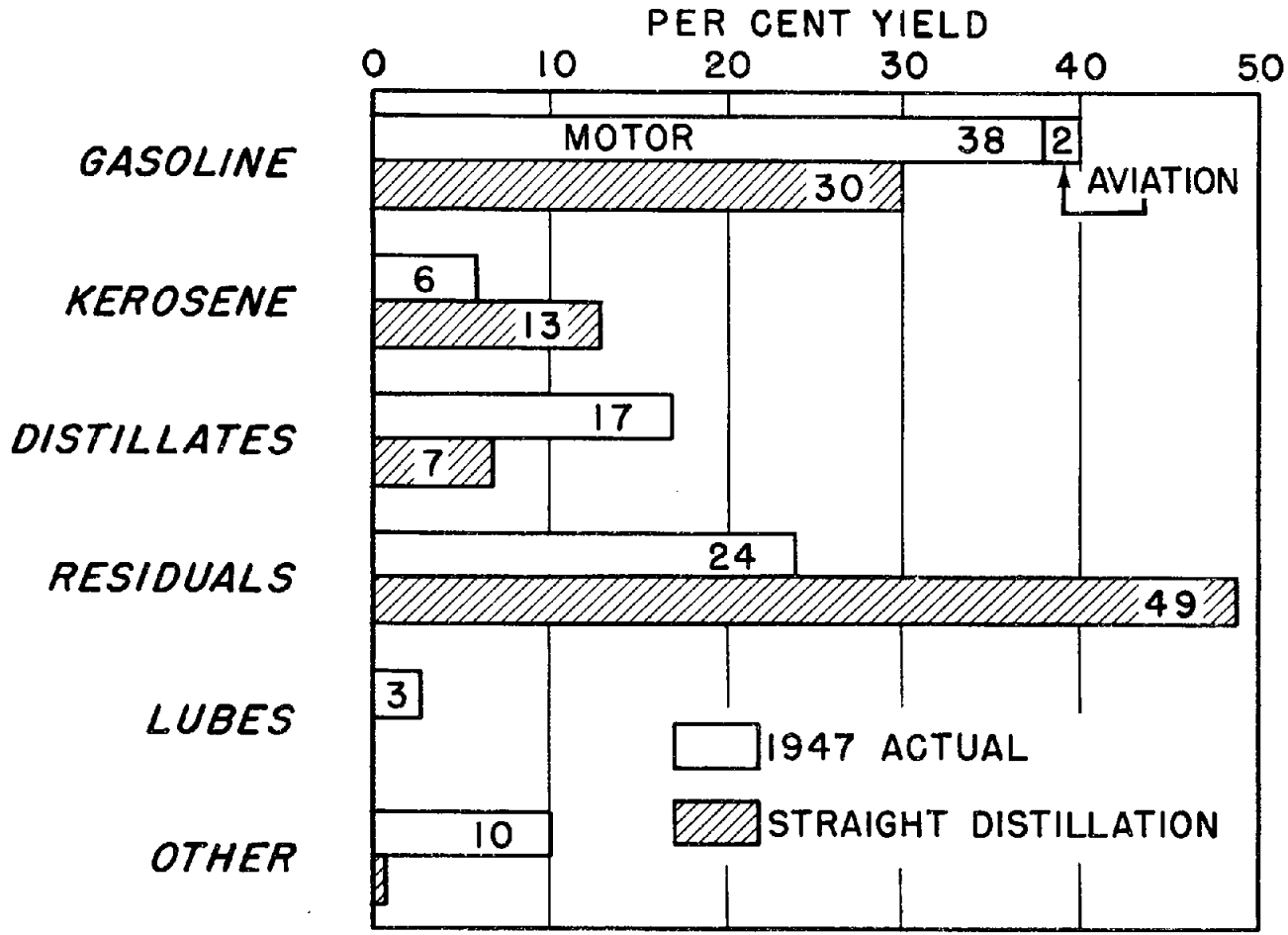

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Chart 15

REFINERY YIELDS

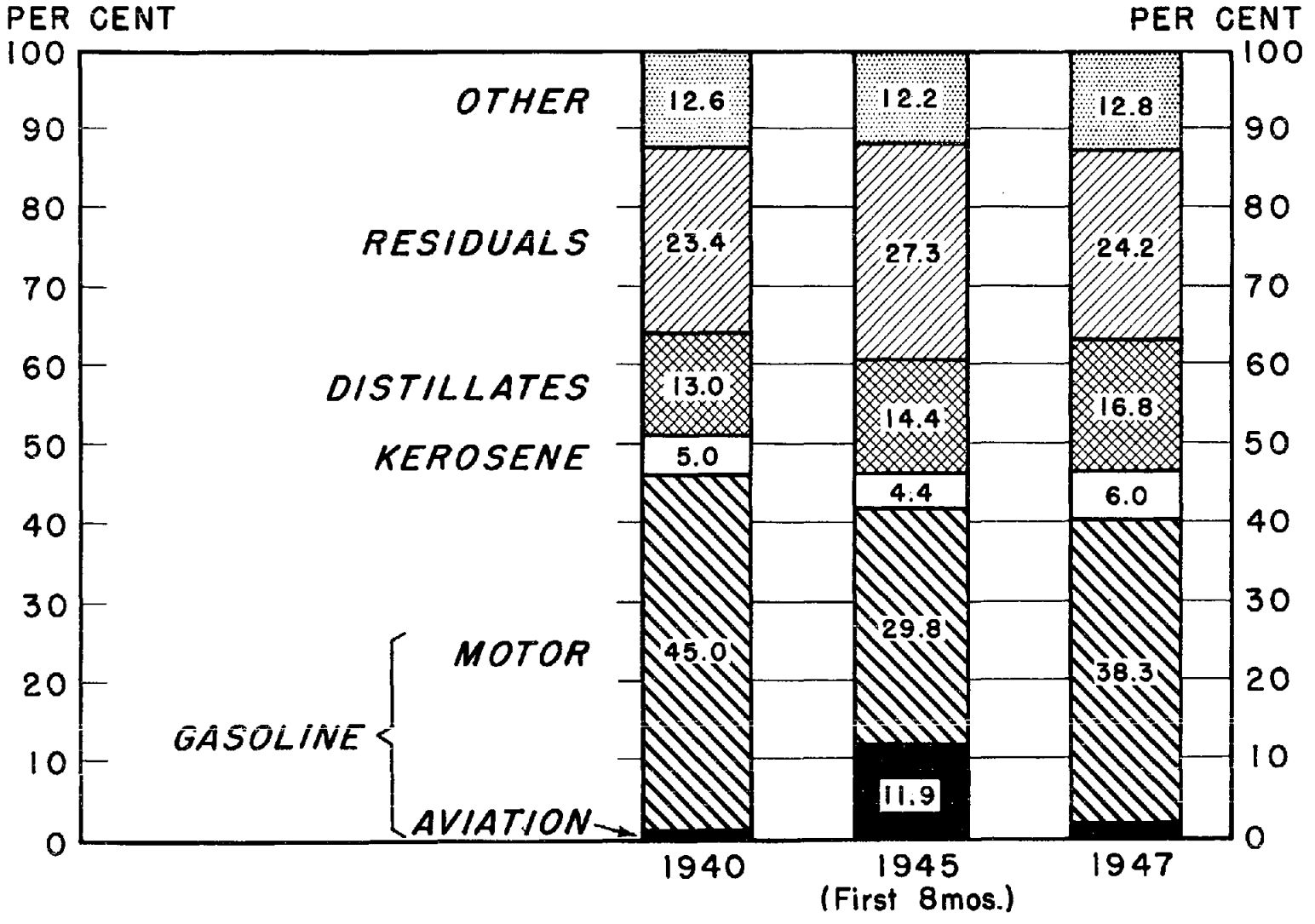

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Chart 16

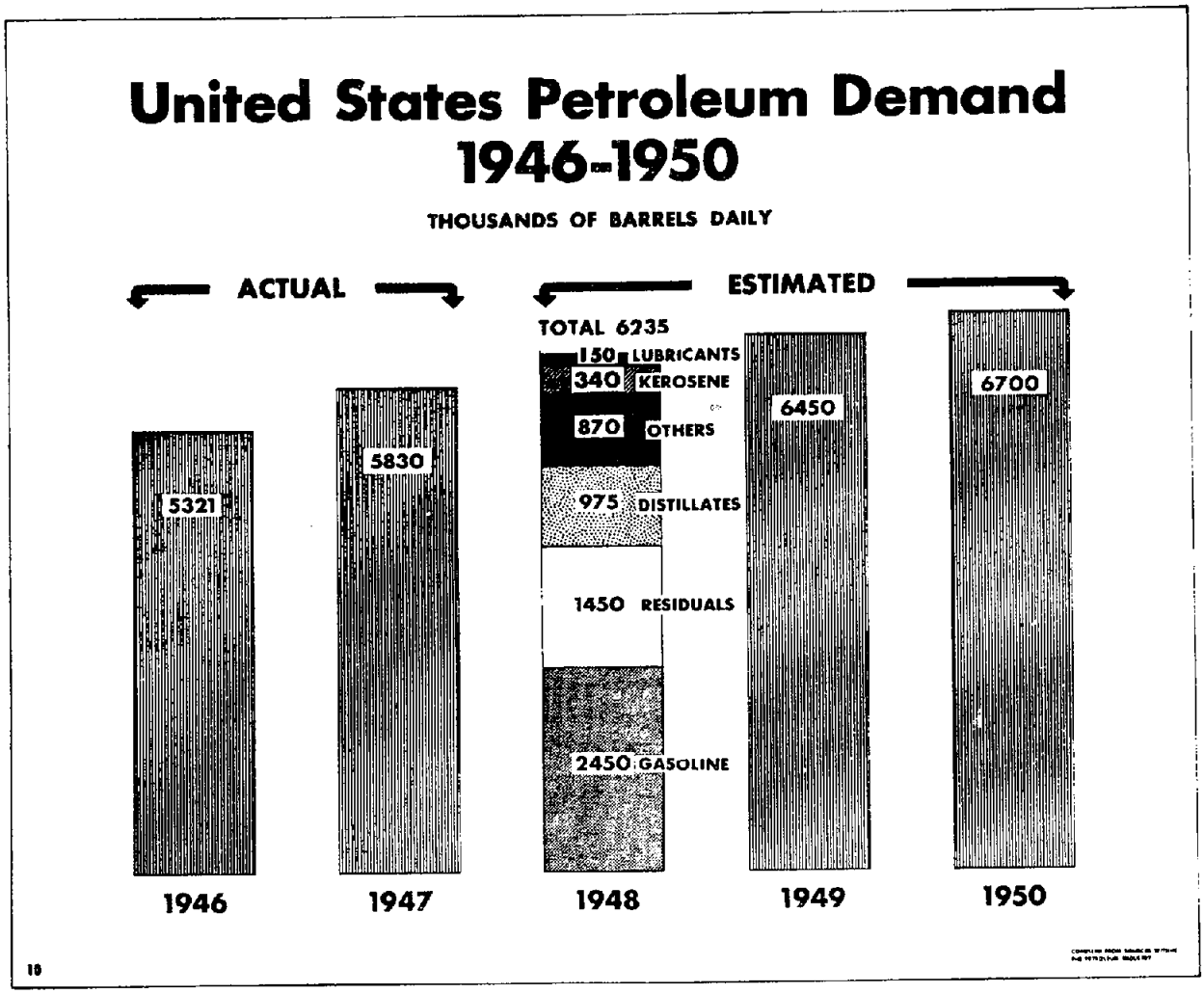
United States Petroleum Demand
1946-1950
THOUSANDS OF BARRELS DAILY
ACTUAL
ESTIMATED
TOTAL 6235
150 LUBRICANTS
340 KEROSENE
870 OTHERS
975 DISTILLATES
1450 RESIDUALS
2450 GASOLINE
5321
5830
6450
6700
1946
1947
1948
1949
1950
10

Chart 17

SOURCES OF ENERGY IN THE U.S.
PER CENT OF TOTAL

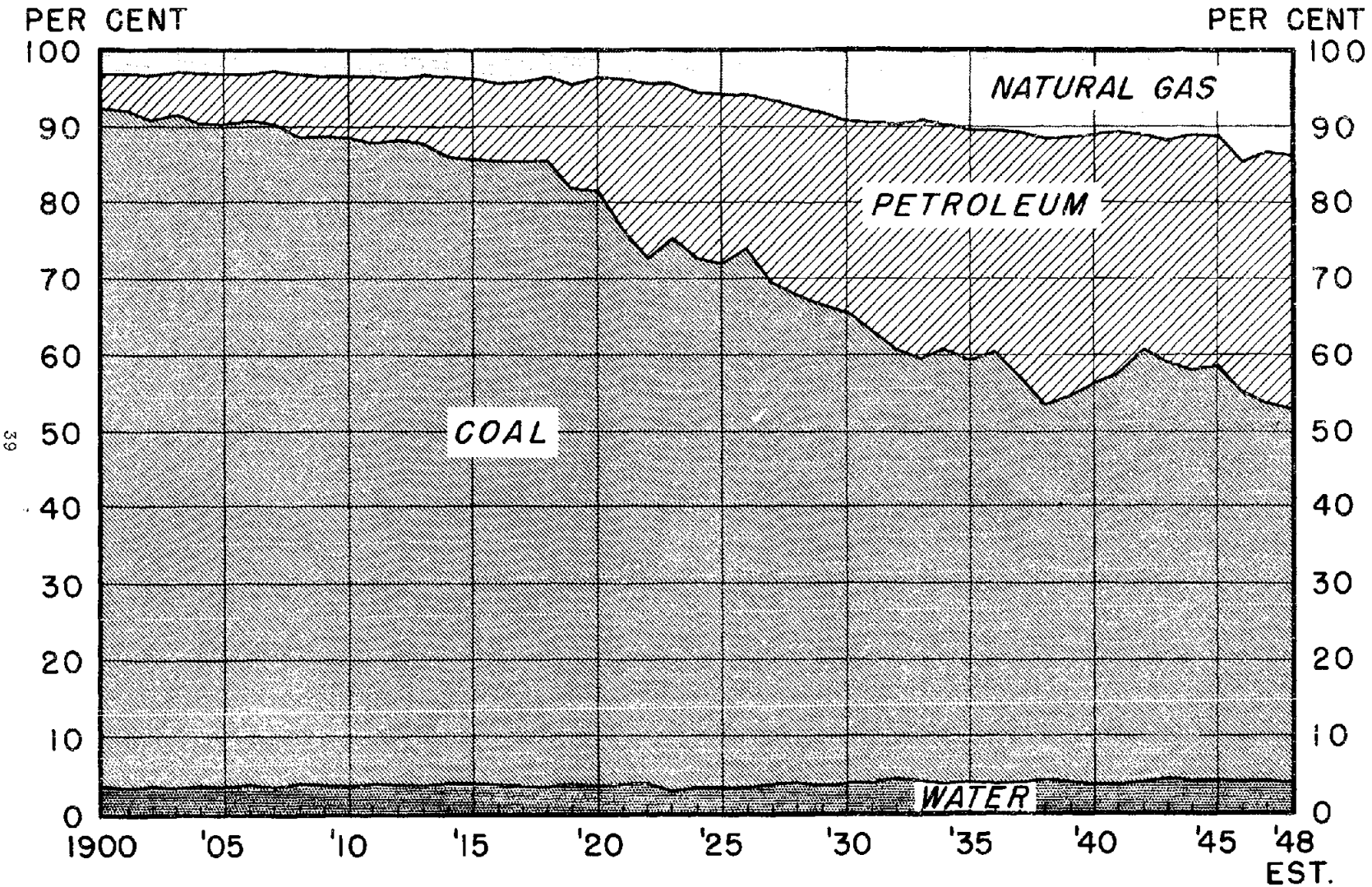

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Chart 18

IMPORTS-EXPORTS

CRUDE-OIL AND PRODUCTS

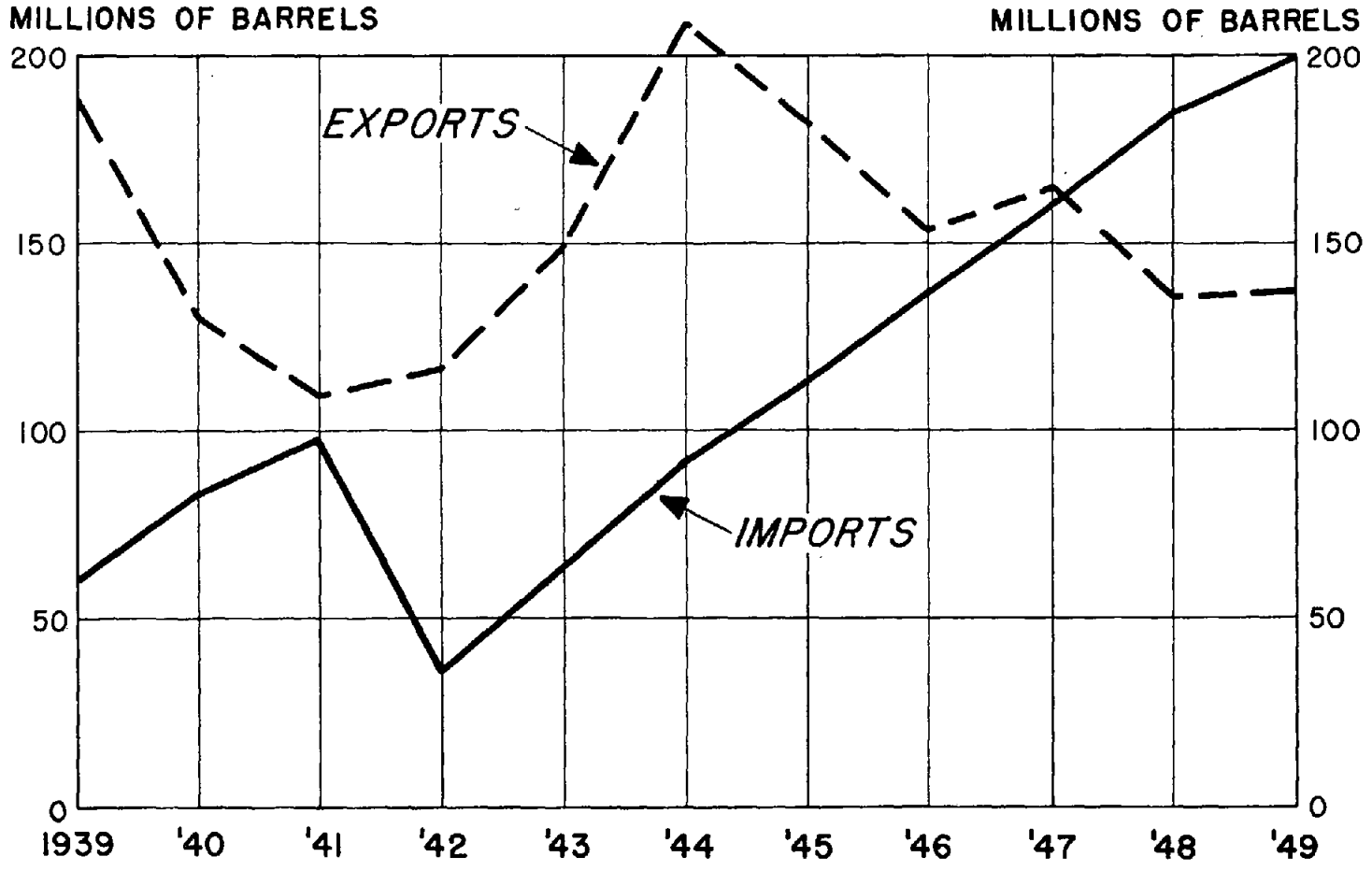

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Chart 19

CRUDE-OIL IMPORTS
BY COUNTRY OF ORIGIN

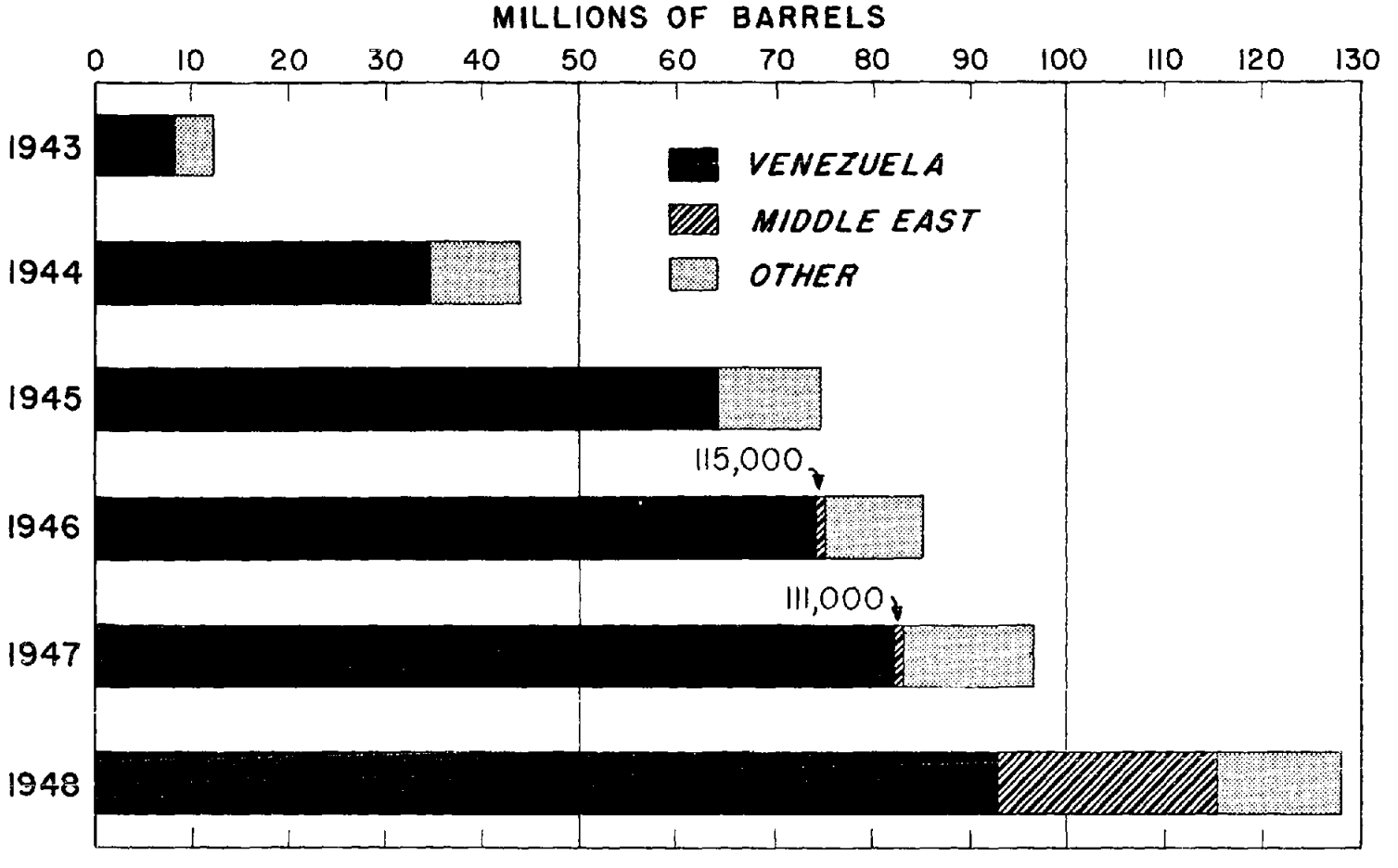

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Chart 20

DEMAND FOR PETROLEUM

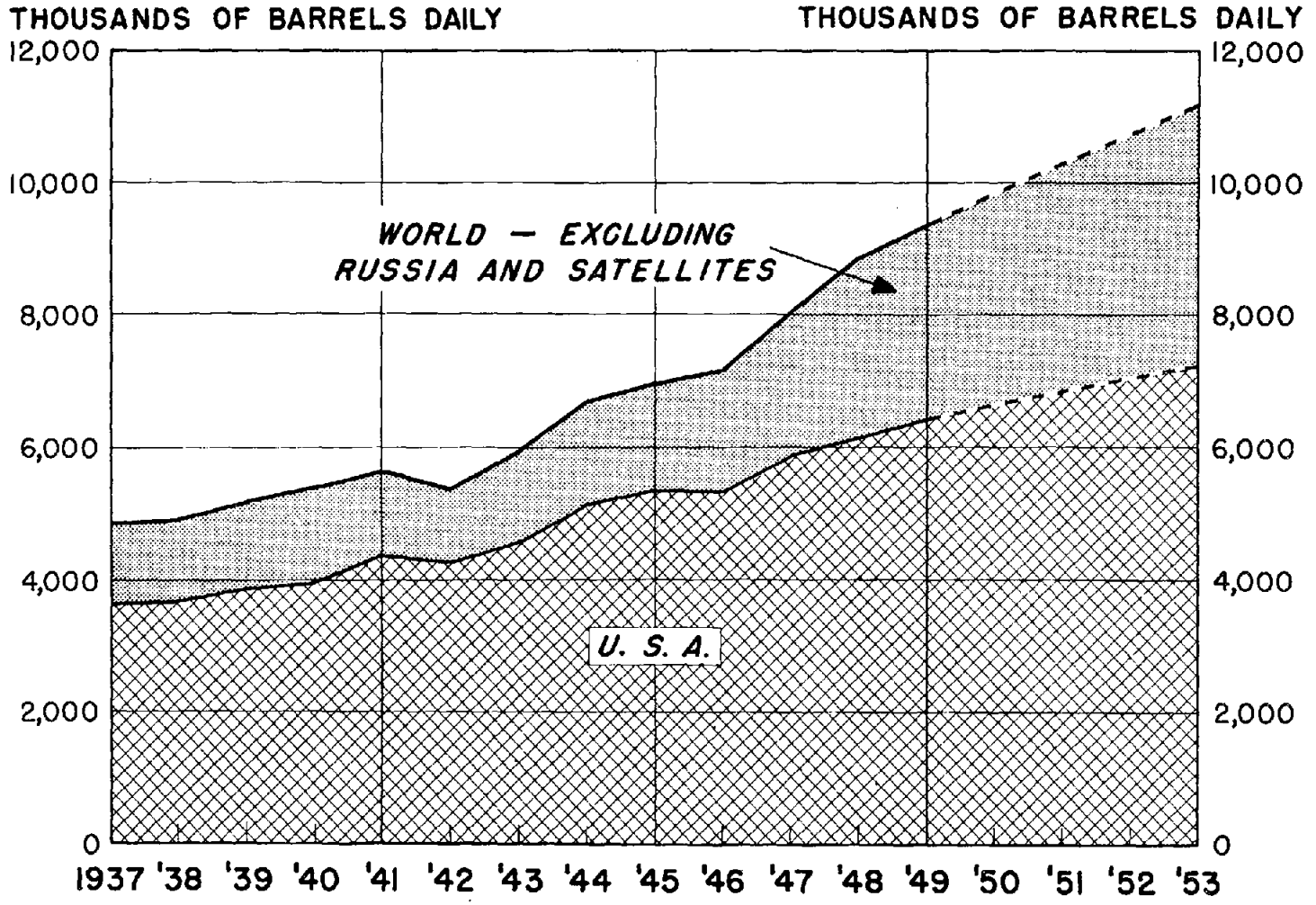

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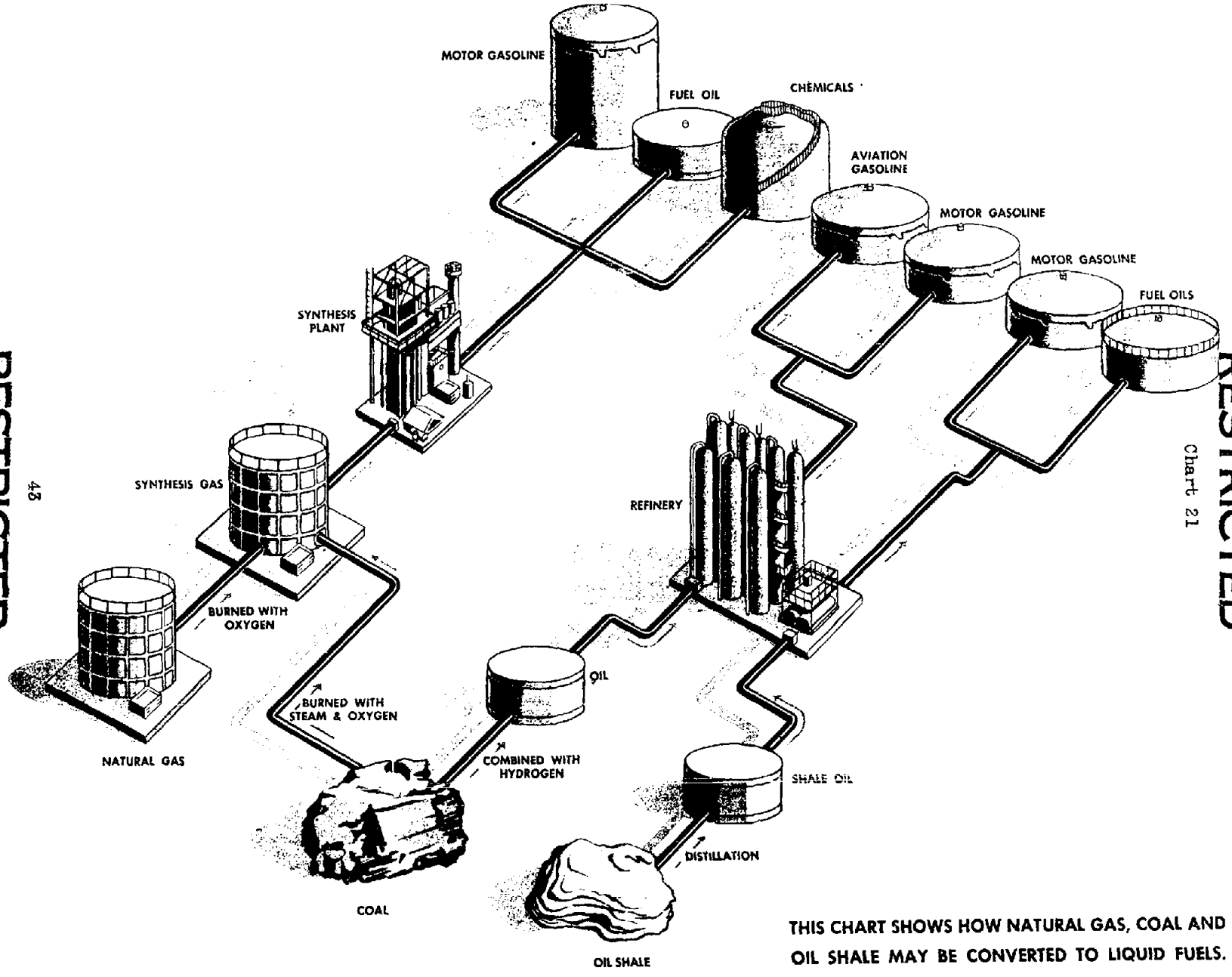
Chart 21



THIS CHART SHOWS HOW NATURAL GAS, COAL AND OIL SHALE MAY BE CONVERTED TO LIQUID FUELS.