PLASTICS AND PETROCHEMICALS IN TIME OF MOBILIZATION

17 February 1954

1383

CONTENTS

Page

INTRODUCTION--Mr. A. H. Baum, Member of the Faculty, ICAF 1

SPEAKER--Dr. Raymond H. Ewell, Assistant Director, National Science Foundation 1

GENERAL DISCUSSION 27

NOTICE: This is a copy of material presented to the resident students at the Industrial College of the Armed Forces. It is furnished for official use only in connection with studies now being performed by the user. It is not for general publication. It may not be released to other persons, quoted or extracted for publication or otherwise copied or distributed without specific permission from the author and the Commandant, ICAF, in each case.

Publication No. L54-96

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Dr. Raymond H. Ewell, Assistant Director, National Science Foundation, was born in Brockton, Massachusetts, 18 June 1908. He received his B. S. degree from the University of Toledo, 1928; M. S., Purdue University, 1930; Ph. D., Princeton University, 1937. From 1930-35 he was a research chemist, Ceramics Division of the National Bureau of Standards; 1937-41, assistant professor of physical chemistry, Purdue University; 1941-45, senior technical aid, Chemical Engineering Division, National Defense Research Committee (Medal of Merit); 1945-48, senior chemical economist, Economic Research Department, the Shell Chemical Corporation, San Francisco; 1938-53, chairman of chemistry and chemical engineering research, Stanford Research Institute and manager of the Institute's Chemical Economics Service. At Stanford, Dr. Ewell also was supervising editor of the Chemical Economics Handbook, making economic surveys for the chemical, petroleum, and allied process industries. He is coinventor of the Leckey-Ewell packing for fractionating columns. For his war work he received the Medal of Merit. Dr. Ewell is a member of the American Chemical Society, American Institute of Chemical Engineers, Society of Rheology, Western Chemical Market Research Association, and Commercial Chemical Development Association. Since the first of this year he has been Director of Program Development of the National Science Foundation. This is his first lecture at the Industrial College.

PLASTICS AND PETROCHEMICALS IN TIME OF MOBILIZATION

17 February 1954

MR. BAUM: Admiral Hague, General Greeley, gentlemen: Plastics and petrochemicals, two products of the organic chemical industrial complex, are of exceptional importance to our domestic economy and to national defense. Behind these products are young, vigorous, mushrooming industries and the inventiveness, the research, and the ingenuity of chemists.

It is most appropriate that we should have as our speaker a chemical engineer, Dr. Raymond H. Ewell, Assistant Director of the National Science Foundation. However, Dr. Ewell is also an economist, an educator, an inventor, and a research administrator.

His experience in the chemical field with both industry and Government, as well as his World War II contributions, eminently qualifies him to speak on our subject this morning, "Plastics and Petrochemicals in Time of Mobilization." Some of you in this year's class already know him from the Technological Progress course. It is my pleasure to introduce for the first time to this platform Dr. Raymond H. Ewell.

DR. EWELL: Admiral Hague, General Greeley, Mr. Baum, members of the faculty and staff of the Industrial College of the Armed Forces: The title of this lecture concerns plastics and petrochemicals. Actually, I am going to turn that order around and talk about petrochemicals first and plastics second. Before getting into petrochemicals, however, I want to talk very briefly about the chemical industry in general. That is an appropriate leadoff subject because to a first approximation the petrochemical industry is the chemical industry, as we will see a little more in detail in a few minutes.

The chemical industry is divided primarily into organic chemicals and inorganic chemicals. Of these two segments the organic chemicals are much larger in dollar value and most of the organic chemicals are petrochemicals. Therefore, to first approximation, we can say the petrochemical industry and the chemical industry are more or less the same thing.

The chemical industry is approximately the eighth largest industry in the United States. It depends to some extent on how it is defined.

The Census Bureau of the Department of Commerce and other Government agencies use the classification called "chemicals and allied products," which in round numbers has sales of about 20 billion dollars a year at the present time. Of these "chemical and allied products," value of 20 billion dollars, about half are what you might call "real chemicals." The "real chemicals" industry--represented by companies such as the Du Pont Company, and the chemical components of Union Carbide and Carbon Corporation, the Dow Chemical Company, and other companies which we usually think of as chemical companies--amounts to about half or 10 billion dollars. The rest are chemical products; namely, pharmaceuticals, soap, paint, and a number of other allied products, chemical in nature, but not really true chemicals.

The chemical industry is particularly distinguished by its high growth rate. The chemical industry has the highest growth rate of any major industry in the United States, and that includes the electronics industry. The chemical industry has been growing at the rate of about 10 percent per year for the past 50 years; that is an enormous growth rate. The average growth rate of all United States industry is 3 percent per year. The chemical industry has consistently maintained a growth rate of over three times the average of our American industry.

Due to this growth, a compound interest rate of 10 percent a year, it has grown in the past, you might say, 15 years from a relatively small peripheral industry to become one of our really basic industries, a basic industry that produces things that we use, material products that we wear as clothing, or live in as houses, and furniture, and thousands of other products that we use every day; whereas 15 years ago, the chemical industry was a small industry. Fifteen years ago, it was not much over a billion dollars a year--which is classified as a small industry--and it was peripheral because it mainly made products used by other industries. It didn't make the basic things which people used. Now it is a basic industry characterized by this very high growth rate.

You can generalize by saying the chemical industry can make virtually any product that a human want might require. Moreover, it can make that product out of almost any raw material. You will see a little bit of the raw materials used by the chemical industry today, but there are many other raw materials which are not being used to the full extent and that could be used when the present raw materials run out. For instance, many of the plastics and synthetic fibers which today are made out of petroleum could be made out of sawdust. It might be more expensive but it would be the same thing.

Chart 1, page 4, --I mentioned earlier that the chemical industry is divided into organic chemistry and inorganic chemistry, and of those two main branches, the organic branch is much the larger in dollar value. This chart will give you a picture of the relative relationship of the organic and inorganic industries. The tonnage of inorganic chemicals is much larger than that of organic chemicals. Some typical examples of inorganic chemicals are sulphuric acid, ammonia, caustic soda, chlorine. Organic chemicals are represented by synthetic fibers, plastics, drugs, synthetic rubber, solvents, antiknock agents, and so on.

Tonnagewise, inorganic chemicals are much larger--78 billion pounds. The dollar value of organic chemicals is higher because they sell at higher prices. So dollarwise organic chemicals are much larger. This shows the relationship between tonnage and dollars. The average price of our inorganic chemicals was 2.5 cents a pound, which would be $50 a ton; organic chemicals average 15.5 cents a pound, which would be $310 a ton.

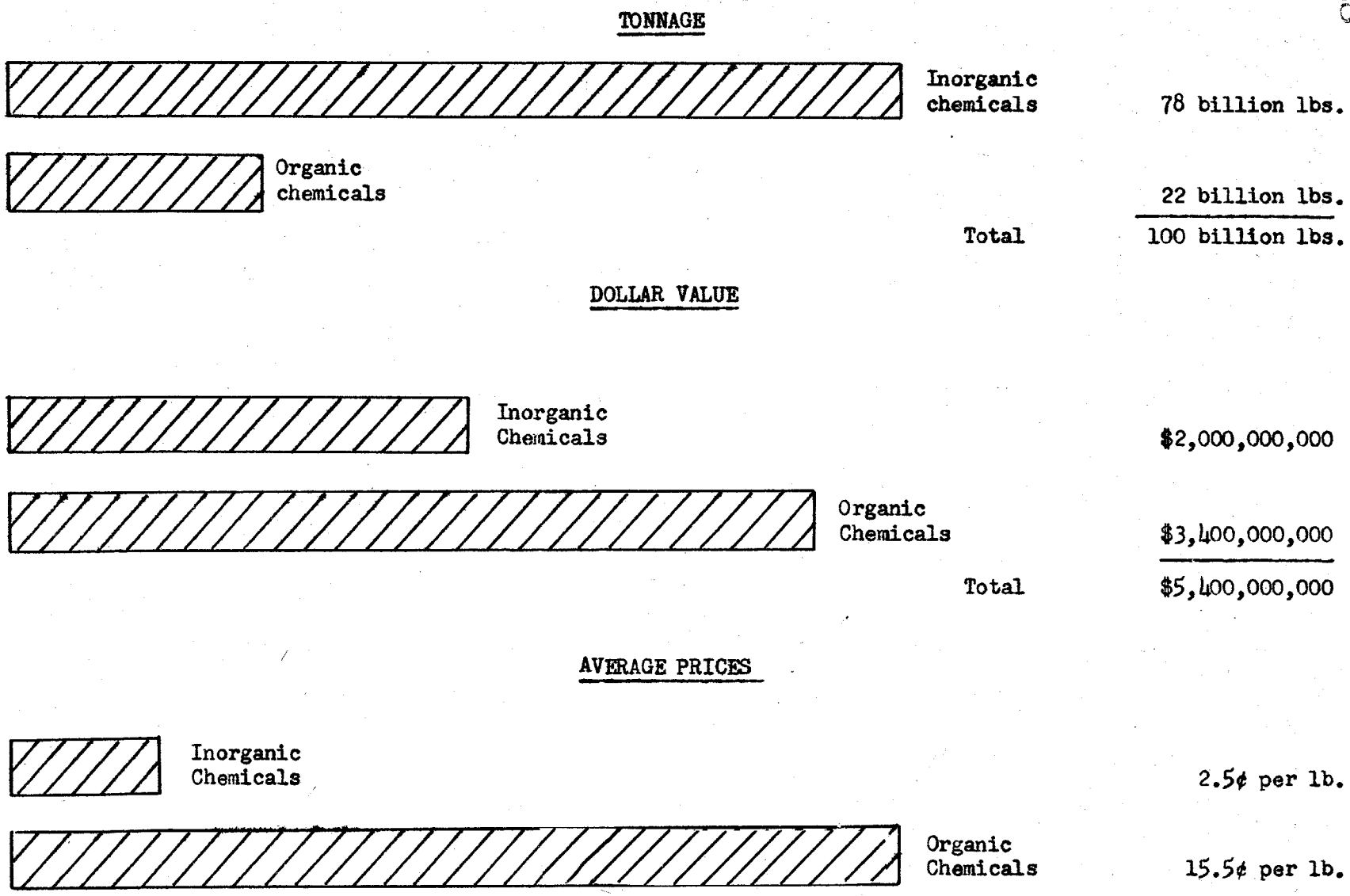
Just what are petrochemicals? Petrochemicals are chemicals which are made from petroleum and natural gas. They are mainly organic in nature, but they are to some extent inorganic. For instance, a typical organic product made from petroleum is plastic--some of the new plastics are polyvinyl, polystyrene; a typical inorganic chemical--made from natural gas primarily--is ammonia. In fact, most of the ammonia made in the United States--which we all know is very important in warfare--is made from natural gas.

Just where is the petrochemical industry located? The petrochemical industry originally was located primarily in Texas because that is where the petroleum and natural gas are; it is still largely located in Texas, although it has been branching out. There are many large units of the petrochemical industry in Louisiana, Oklahoma, Arkansas, Kansas, and now it is even moving up into the Midwest. For instance, one of the largest recent petrochemical plants is in Tuscola, Illinois, built by the National Distiller's Corporation. This plant is operated by the National Petro-Chemical Corporation, a subsidiary of National Distillers, and is built on the pipeline that goes from Texas to Chicago. This plant takes out one-third of all the gas that goes to Chicago by this pipeline. It is the largest synthetic alcohol plant in the world. Other companies make more synthetic alcohol than National Distillers do, but this is the largest single plant.

Another petrochemical plant which just opened a few weeks ago is that of Sun Oil Company in Philadelphia, the first important petrochemical plant on the eastern seaboard--located right on salt water. This

CHART 1

Organic vs. Inorganic Chemicals (1952)



plant of Sun Oil Company is the largest benzene plant in the country and probably in the whole world. Benzene is a comparatively recent petrochemical derived from petroleum. Various plants along this line have been built. Sun Oil recently opened this one, which is the largest.

Chart 2, page 6.--I mentioned that organic chemicals is the largest portion of petrochemical industry. This chart shows how predominantly organic chemicals are petrochemicals. The first bar shows the production of organic chemicals from petroleum and natural gas as of 1952--16 billion pounds. In other words these are the petrochemicals; plastics, fibers, solvents, antiknock agents are among the principal examples. This is not counting inorganic chemicals at all. A relatively small amount is made from coal; a slightly smaller amount from wood and cotton--mainly rayon and cellophane; from grains and molasses; from fats and oils; from rosin and turpentine; from tall oil. This comprises, with some minor exceptions, all the organic chemicals produced by the chemicals industry. So the chemical industry is overwhelmingly the petrochemical industry.

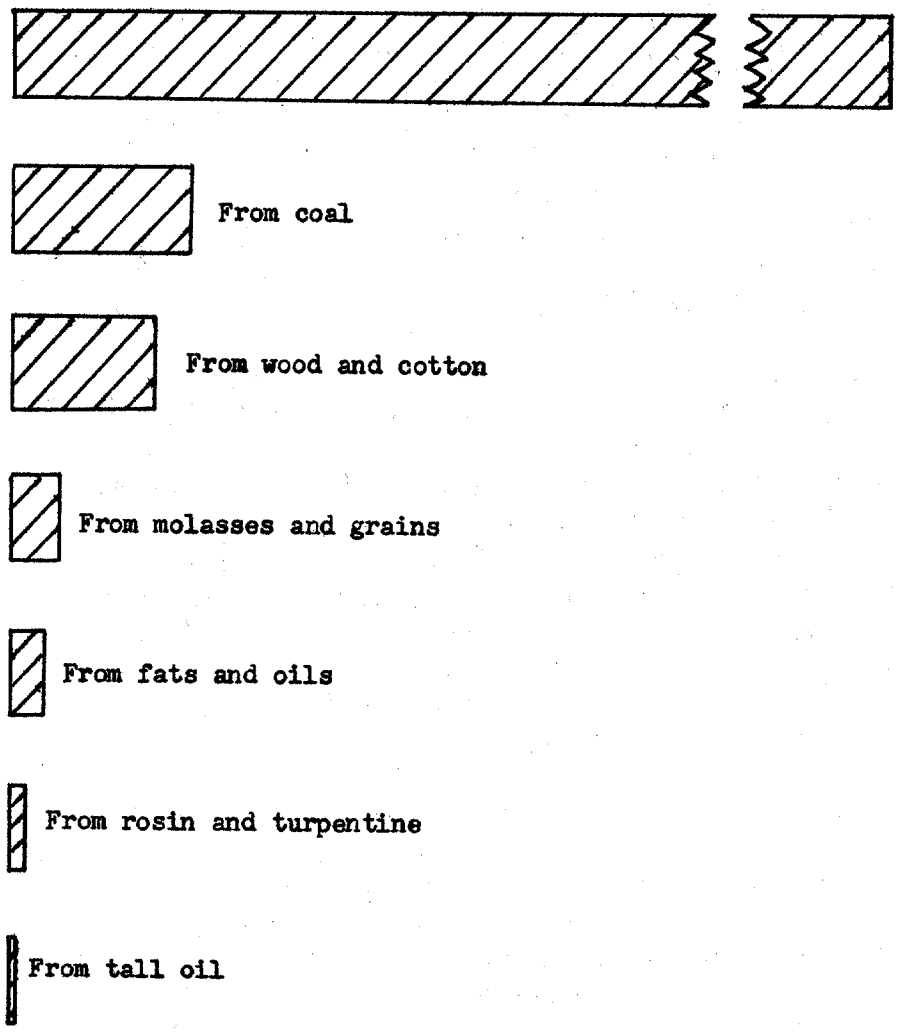
Chart 3, page 7.--This chart shows the very rapid growth rate of the petrochemical industry. Here are some fancy words which I will try to define very briefly--aliphatics and aromatics. Aliphatics and aromatics together comprise organic chemicals. Aromatics are a type of organic chemical, in which the atoms just happen to be in rings; they are sometimes called cyclic chemicals. Aliphatics have open chains of carbon atoms. Commercially, there is no difference between the two; both make plastics. Aliphatics and aromatics, the two together comprise organic chemicals. You can see the very rapid growth of the chemical industry. Of course, this goes a little bit into the future. We are right here at the present time (indicating 1953).

Chart 4, page 8.--This chart is just a little elementary chemistry. I thought it would make this petrochemical business a little more concrete if I showed you how an end product arises from a starting material. This has five different sequences of products, starting with the raw material and ending with the end product. This starts with petroleum, goes through heat and the catalytic cracking process, to get ethylene, which is a byproduct from cracking. The ethylene is treated with hydrochloric acid, which gives one ethyl chloride. Then it is treated with lead alloy, which gets lead into the molecule, and we end up with tetraethyl lead, a well-known antiknock agent, which, as you know, is an ingredient of automotive and aviation gasoline. That is one simple example of the petrochemical business. Practitioners of this art are the Ethyl Corporation and the Du Pont Company.

CHART 2

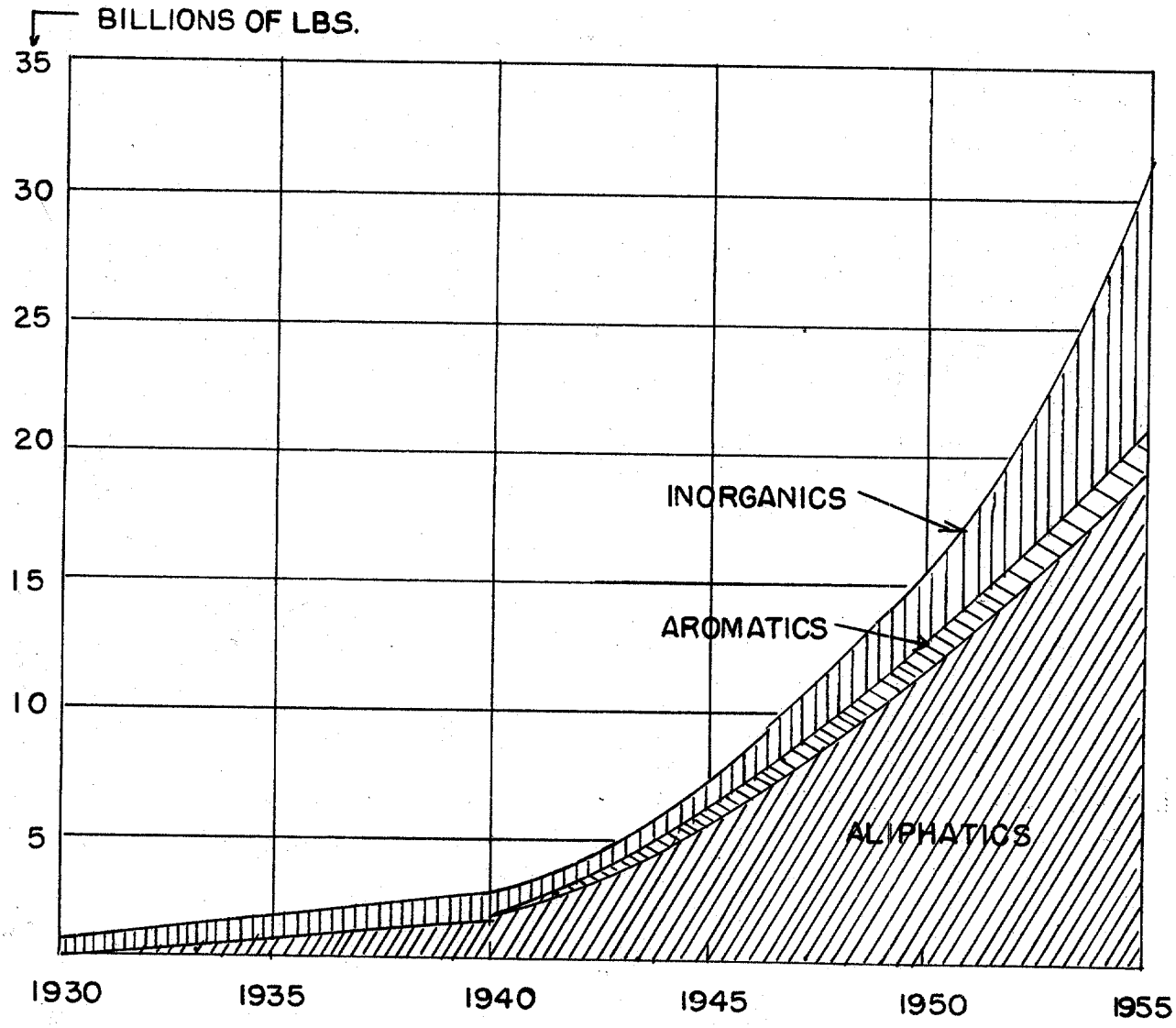
PRODUCTION OF ORGANIC CHEMICALS (1952)

(Breakdown by raw material)



	Billions of pounds
From petroleum and nat. gas	16
From coal	2.5
From wood and cotton	2
From molasses and grains	0.7
From fats and oils	0.5
From rosin and turpentine	0.2
From tall oil	0.1
Total	22

U. S. PETROCHEMICAL PRODUCTION
(EXCLUDING CRUDES)



U.S. PETROCHEMICAL PRODUCTION BY YEARS, 1930 THROUGH PROJECTED FIGURES FOR 1955. FIGURES EXCLUDE CRUDE PRODUCTS.

CHART 4

STEPS IN MAKING SOME IMPORTANT PETROCHEMICALS

Petroleum $\xrightarrow{\text{heat}}$ H-C=C-H (ethylene) $\xrightarrow{+\ \text{H-Cl}}$ H-C—C-Cl (ethyl chloride) $\xrightarrow{+\ \text{Pb alloy}}$ $Pb(C_2H_5)_4$ (tetraethyl lead)

H-C—C—C-H (propane) $\xrightarrow{\text{heat}}$ H-C=C-H (ethylene) $\xrightarrow{+\ O_2}$ H-C—C-H, O (ethylene oxide) $\xrightarrow{+\ H_2O}$ H-C—C-H, O O, H H (ethylene glycol)

H-C-H (methane) $\xrightarrow{\text{heat}}$ H-C≡C-H (acetylene) $\xrightarrow{+\ \text{H-Cl}}$ H-C=C-Cl (vinyl chloride) $\xrightarrow{\text{polym.}}$ $(\text{H-C—C-Cl})_x$ (polyvinyl chloride)

H-C-H (methane) $\xrightarrow{+\ H_2O}$ CO_2 (carbon dioxide) + H_2 (hydrogen) $\xrightarrow{+\ N_2}$ NH_3 (ammonia) $\xrightarrow{+\ O_2}$ HNO_3 (nitric acid)

Petroleum $\xrightarrow{\text{cat.}}$ C_6H_6 (benzene) $\xrightarrow{+\ \text{ethylene and heat}}$ $C_6H_5C{=}C\text{-}H$ (styrene) $\xrightarrow{\text{polym.}}$ $(C_6H_5C{=}C\text{-}H)_x$ (polystyrene)

Another example is propane. There are three carbon atoms in a molecule of propane, a common constituent of all natural gases. It also occurs in the off-gases from petroleum refineries. Propane is cracked with heat to get ethylene, which is the same as the ethylene in the previous example. This is oxidized with catalysts to get ethylene oxide. Oxygen is introduced into the molecule. That then is treated with water, under the right conditions, again these catalysts come into the picture, and we get ethylene glycol. This is used in automotive antifreezes and liquid coolants for airplane engines.

Here is another important example of a petrochemical, starting with methane, the principal component of natural gas--hydrocarbon which comprises most natural gas--heated under the right conditions, gives acetylene. Add hydrochloric acid to that and you get a molecule called vinyl chloride. This polymerizes in a chain which makes a plastic called polyvinyl chloride, represented by plastic curtains and so on.

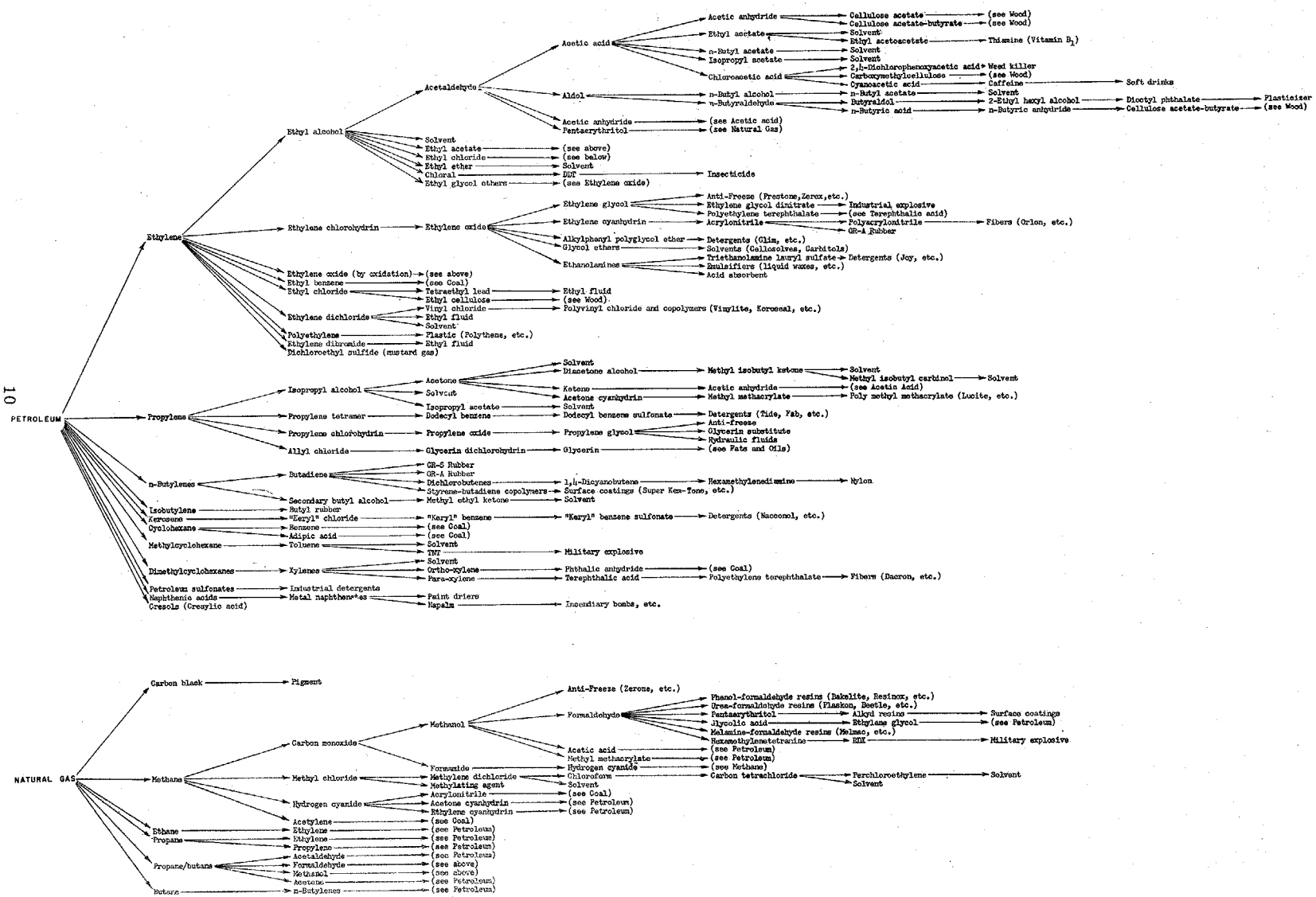
Here is methane again, which will wind up here as ammonia, and finally nitric acid. Ammonia has no carbon. This is an example of using natural gas in which the carbon is not used. Methane treated with water (steam) under the right conditions produces carbon dioxide. Hydrogen derived from methane and nitrogen derived from the distillation of liquid air together make ammonia. You are all aware of the fact that we need ammonia to fight wars. Add oxygen to the ammonia and you get nitric acid; from nitric acid, you get TNT, RDX, and virtually all other explosives.

The last example, which illustrates the aromatic type of petrochemicals, starts with petroleum and by a catalytic process we get benzene. By adding ethylene and heat, we convert benzene into styrene, which is used, of course, to make synthetic rubber. Also I show here the polymerizing process to get the plastic polystyrene, which is the largest of all plastics. It is the transparent plastic that you see everything made out of in the 10-cent store. Many military articles are also made of polystyrene.

Chart 5, page 10.--This shows the entire petrochemical industry on one chart. It starts with petroleum and natural gas here (indicating): These are the various steps, and out here on the right-hand periphery are the end products. I will read a few of them: vitamin B; weed killer 2.4-D; synthetic caffeine; DDT insecticide; Prestone antifreeze; industrial explosives; synthetic fibers; Glim detergent; Joy detergent;

CHART 5

FLOW CHART OF PETROCHEMICALS



1394

Tide detergent; Lucite; hydraulic fluids; nylon fibers and plastics; dacron fiber; bakelite resins, as well as many other resins; various solvents, insecticides, and so forth. These are the end products, things that we buy in the store and use every day personally. Many of them also have military applications. But I just show you this en masse to show the enormous series of processes and the end products which are derived from the two starting materials, petroleum and natural gas.

Chart 6, page 12.--The petrochemical industry has become so important to the country as a material producer, what is the situation with raw materials with regard to making petrochemicals? Do we have plenty of raw materials? This picture shows that of all petroleum, 3 percent is used to make petrochemicals--maybe only 2 percent; something of that order anyway. It is hard to calculate exactly. Two or three percent of all petroleum is used to make petrochemicals; 93 percent is used to make fuels and lubricants. The conclusion to be drawn from this is that there is plenty of room for expansion in the production of petrochemicals from petroleum. If it ever gets too big and they have to start cutting down on the petroleum available for fuels, there may be some economic consequences.

With natural gas the picture is pretty much the same. It is used mostly for fuel--space heating and other types of fuel uses. A significant amount is used to make carbon black. Something on the order of 3 percent is used to make petrochemicals. These percentages on both petroleum and natural gas are increasing rather rapidly because the production of petrochemicals is increasing much faster than either the production of petroleum or natural gas.

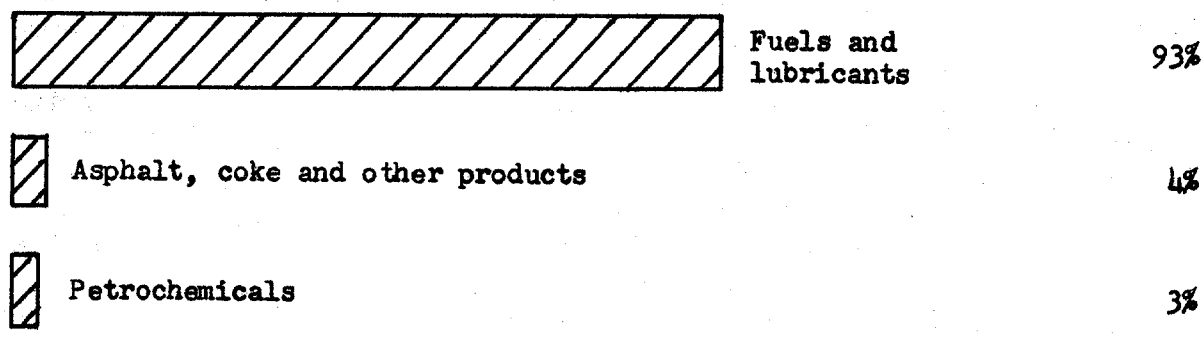
Now in a nutshell, what are petrochemicals used for? We have seen a lot of individual instances--fibers, plastics, and so forth. This slide gives a breakdown of end uses of petrochemicals on a rather broad basis.

Chart 7, page 13.--Rubber is the largest single user of petrochemicals, mainly synthetic rubber, but there would be some of the rubber processing chemicals that are used to make rubber products. Automotive and aviation together may be the second largest use--for instance, tetraethyl lead and glycol antifreeze would be two big items in here although there would be many others. Next would be synthetic fibers--nylon, orlon, dacron, acrilan; others are on the verge of coming into the market. Fifteen percent of all petrochemicals go into synthetic fibers; 14 percent, plastics; 11 percent agriculture--mainly ammonia

CHART 6

Distribution of Resources for Petrochemicals (1952)

PETROLEUM



NATURAL GAS

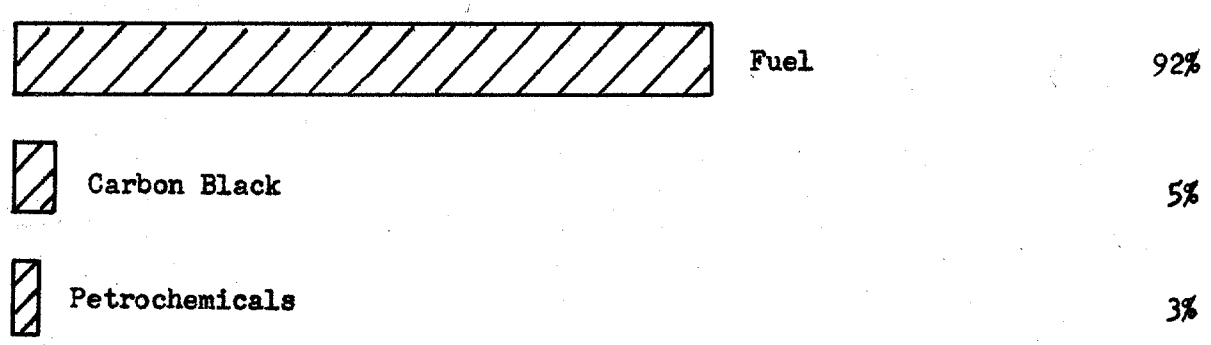
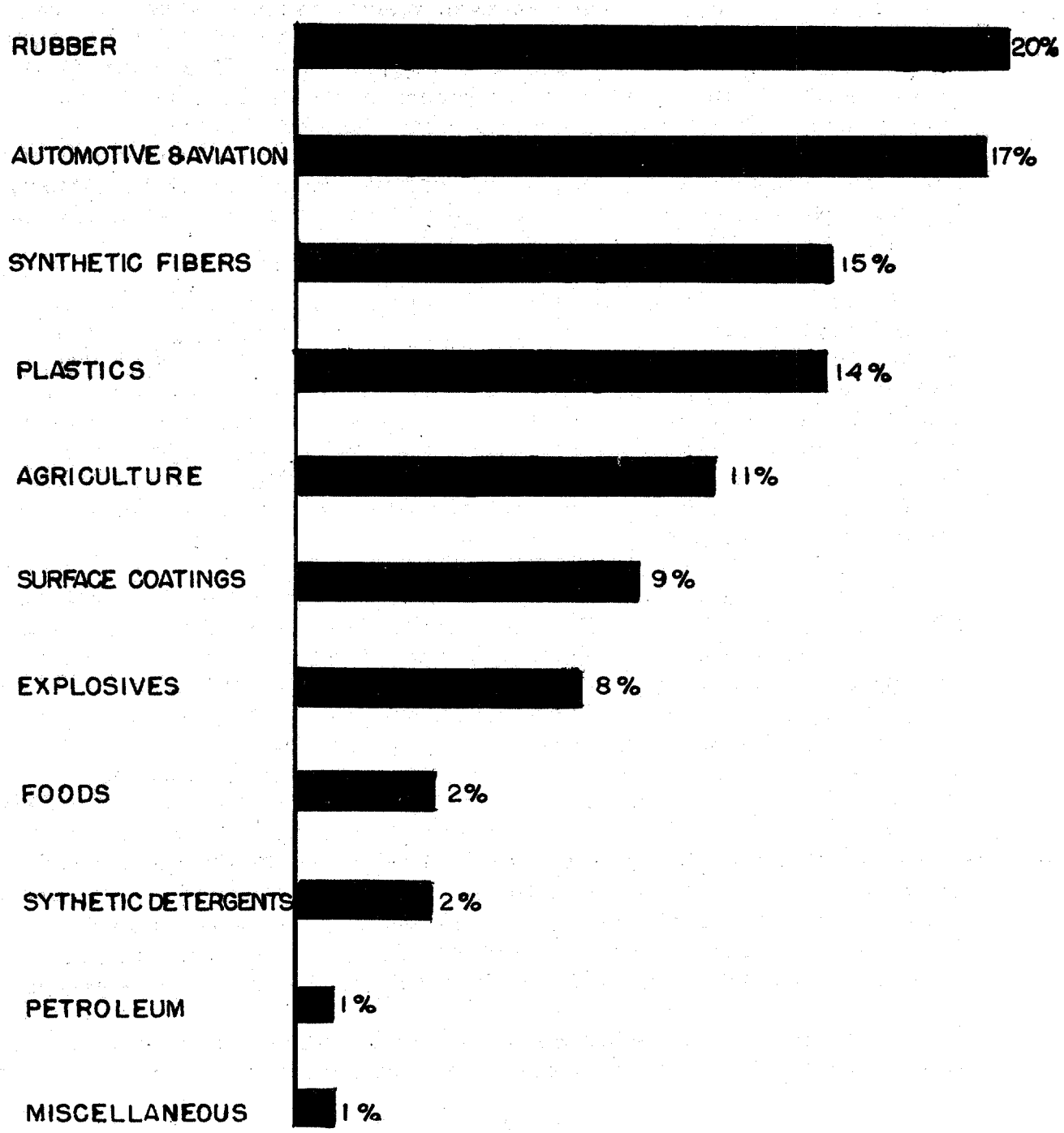


CHART 7

PETROCHEMICAL END USES

1952 PERCENTAGE BREAKDOWN ON A TONNAGE BASIS



for fertilizers; 9 percent, surface coatings; 8 percent, explosives; and these minor percentages here. This shows where the petrochemicals go.

Chart 8, page 15.--Now before turning to plastics, which is one of the major petrochemicals and deserves special consideration because of its growing importance, I wanted to speak very briefly of rubber and fibers, two other important petrochemical products. This chart gives in a nutshell the impact of synthetic rubber on the whole rubber situation and synthetic rubber is exclusively a petrochemical product. This is on a semilogarithmic graph, running from 10,000 tons to 10 million tons, and from 1910 to 1952. These black dots are the production of synthetic rubber. Natural rubber and reclaimed rubber are a fairly constant percentage of the total.

Natural rubber was our principal source of rubber until 1940; then natural rubber declined very rapidly as a source of rubber. Synthetic rubber came into the breach first in 1942, more in 1943, 1944, 1945, 1946--the peak was in 1946 when synthetic rubber was most of the rubber consumed in the United States. Then in the postwar period, natural rubber came back pretty strong again and surpassed synthetic rubber. With the advent of the Korean war, natural rubber went down again and synthetic rubber went ahead and will probably exceed natural rubber from now on and expand more and more.

Chart 9, page 16.--This chart gives a similar picture on synthetic fibers and natural fibers. This is natural and synthetic fibers in terms of percentage of the total. This is consumption not production. Back around 1920, natural fiber was the whole picture--wool, cotton, and silk. Then they started declining during the twenties. They declined more in the thirties and more precipitously in the forties. By 1920 synthetic fibers had come into the picture and up until 1940 the synthetic fibers were largely rayon made from cotton and wood. Since 1940 synthetic fibers have become increasingly important synthetic products, mainly from synthetic petrochemicals. In 1952 synthetic fibers were up to above 23 percent of the national consumption of fibers, and it seems very likely that natural fibers will continue to decline and synthetic fibers will continue to go up. It would be my guess that they will reach a fifty-fifty point sometime in the early 1960's or the mid-sixties maybe.

Chart 10, page 17.--Now we will turn our attention to plastics for a few minutes. This is another one of the semilogarithmic graphs. I

CHART 8

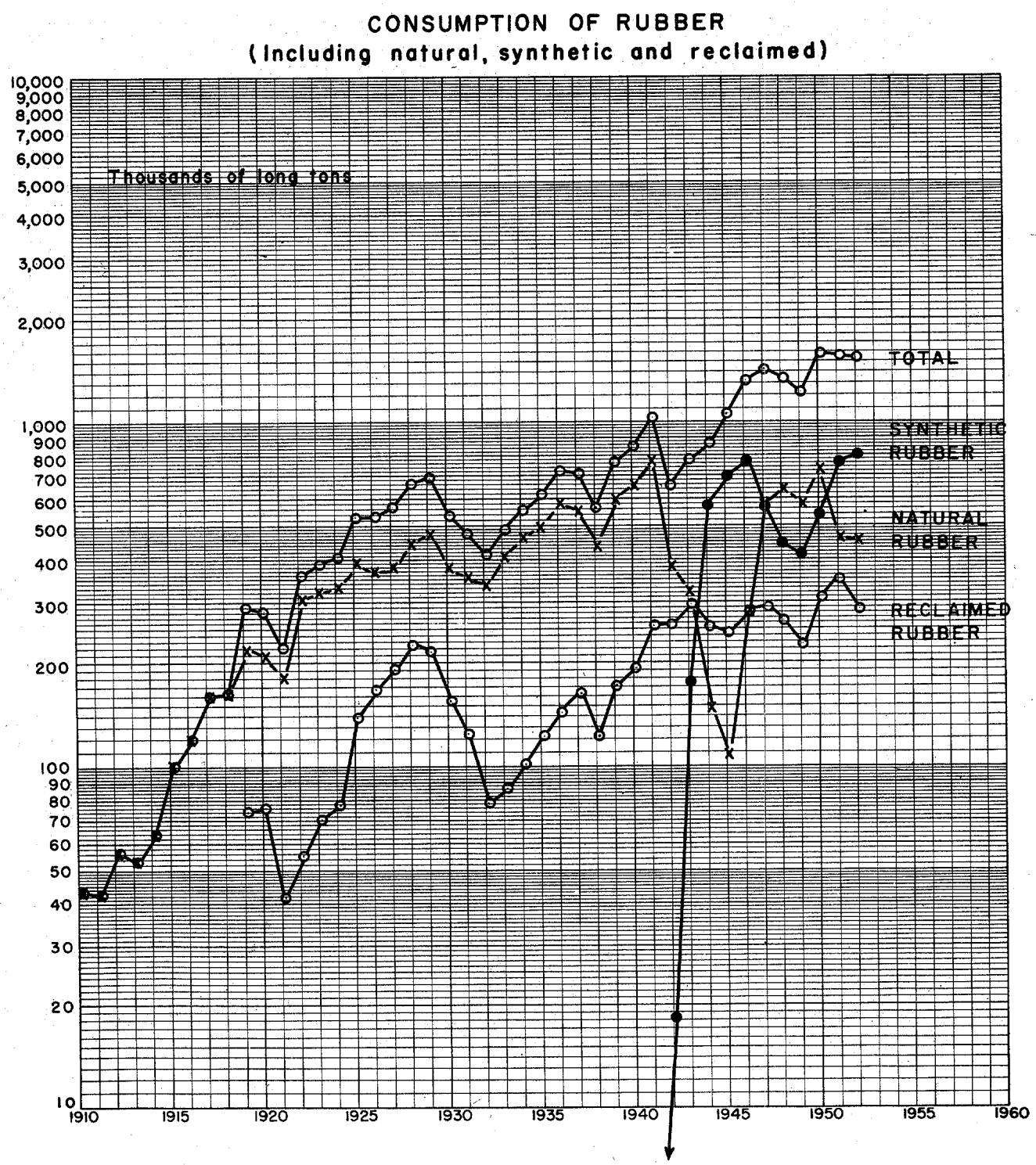

CONSUMPTION OF RUBBER
(Including natural, synthetic and reclaimed)
Thousands of long tons
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
TOTAL
SYNTHETIC RUBBER
NATURAL RUBBER
RECLAIMED RUBBER

CHART 9

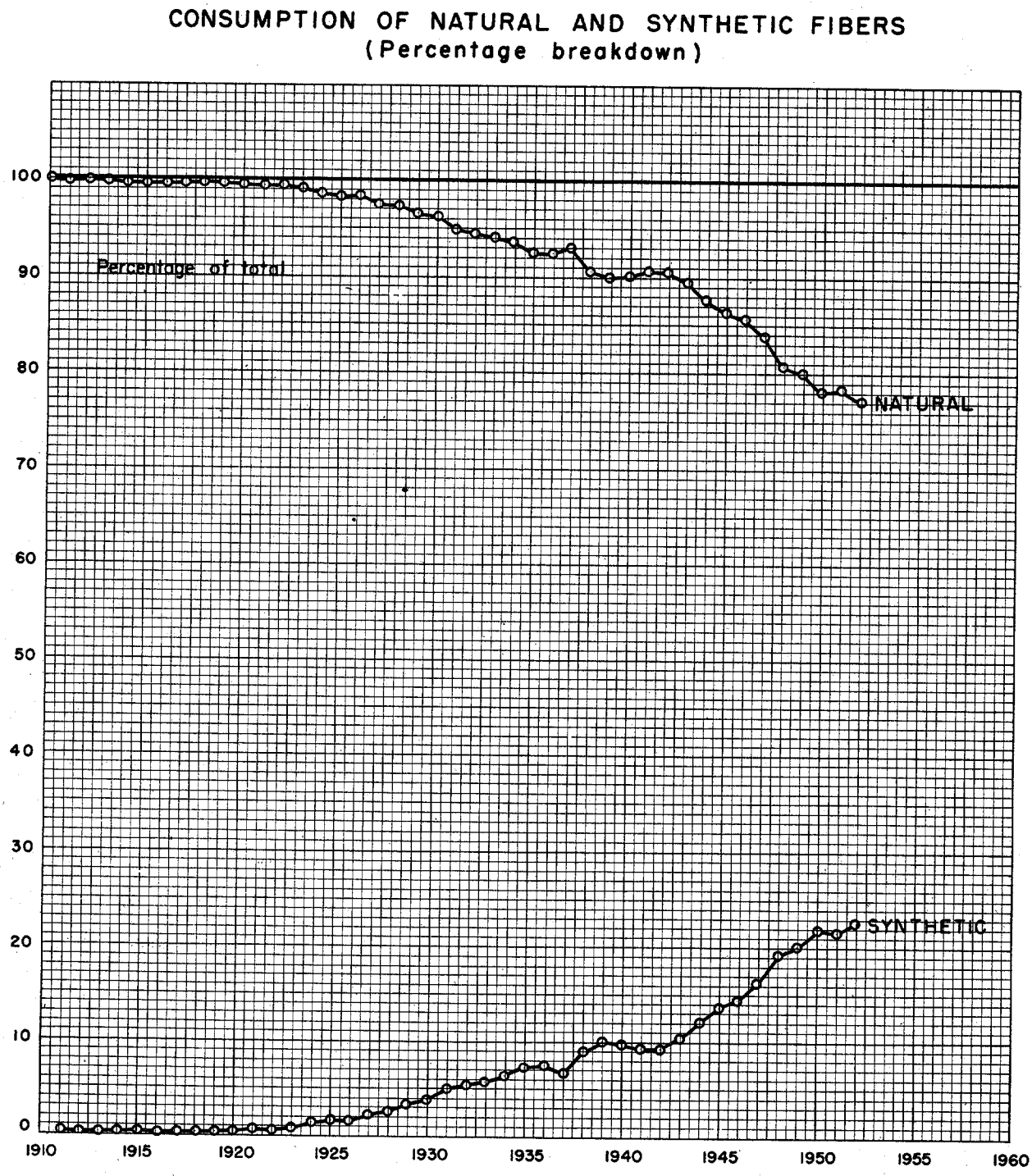
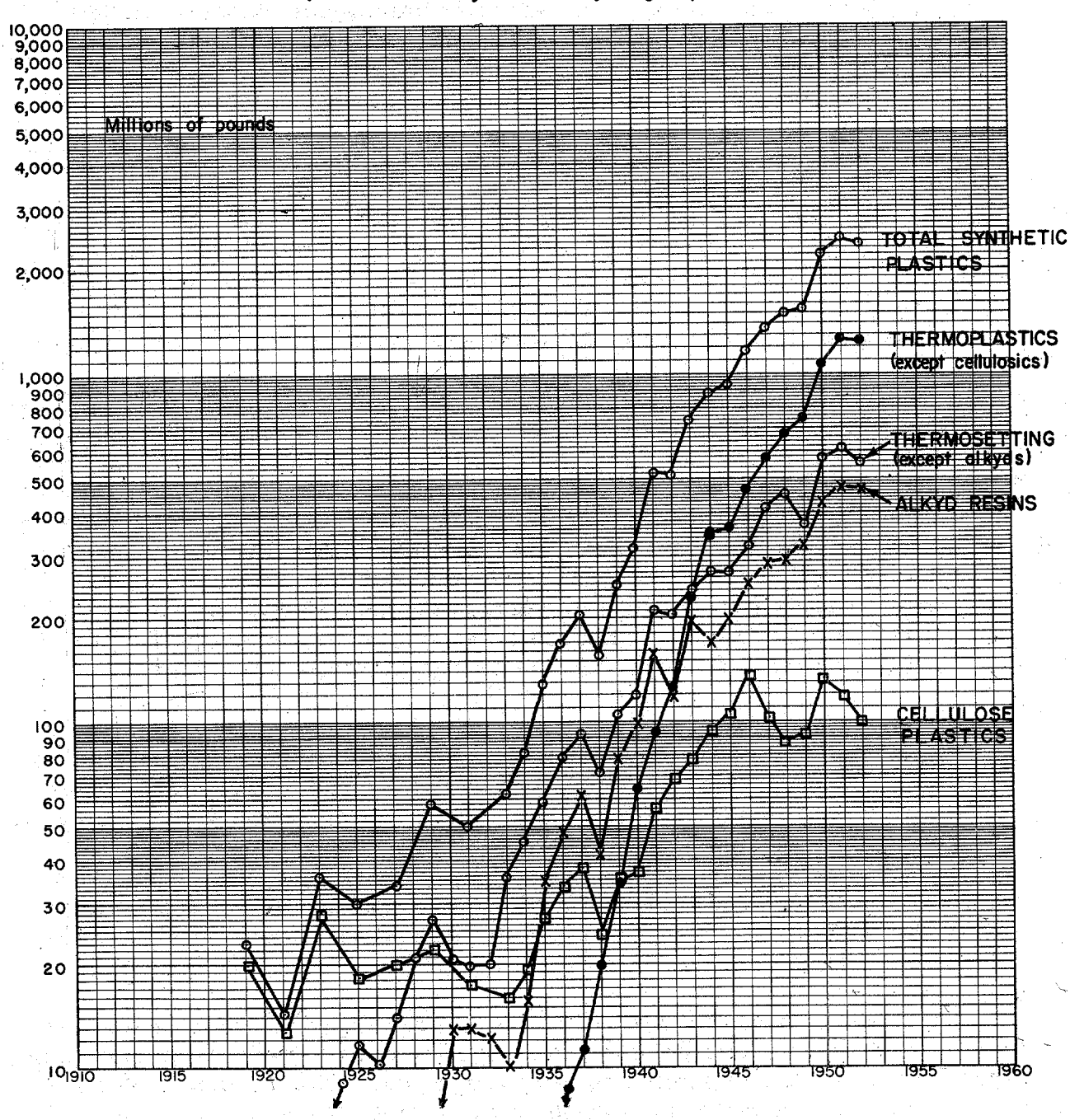

CONSUMPTION OF NATURAL AND SYNTHETIC FIBERS
(Percentage breakdown)
Percentage of total
NATURAL
SYNTHETIC
100
90
80
70
60
50
40
30
20
10
0
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960

CHART 10

PRODUCTION OF SYNTHETIC PLASTICS AND RESINS
(Breakdown by four major groups)



hope this will not confuse you. It is similar to the stock broker's ratio chart with which some of you who deal in the stock market may be familiar.

This shows the enormous growth rate of plastics, which have averaged something over 20 percent per year ever since plastics started, back in the early twenties, although there are a few that go back to 1890. But since the 1920's, plastics have grown at a rate of around 22 or 23 percent per year, which is a fantastically high growth rate.

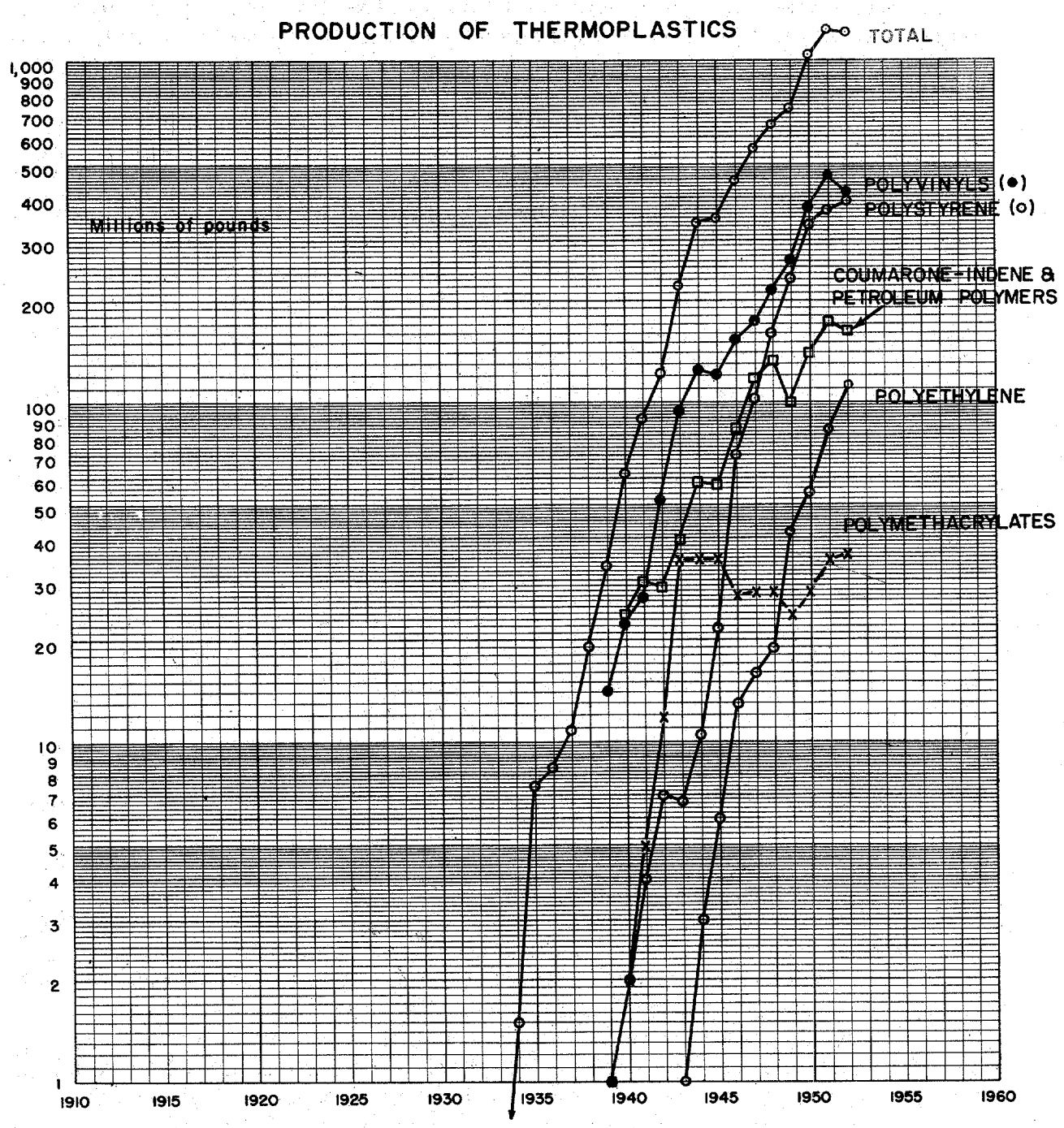
Plastics can be divided into four principal groups--thermoplastics, thermosetting resins, alkyd resins, and cellulosics. Examples of thermoplastics are polystyrene, polyvinyl--shower curtains, raincoats, and so on; polyethylene--squeeze bottles, flexible tumblers, and containers of all sorts. I wish I had brought some samples with me to show you, but you are all familiar with these plastics. Those are examples of thermoplastics. They are plastics which can be melted and remolded.

Thermosetting plastics are those which are similar to the telephone set and which, once molded, stay that way; they can't be melted again. The alkyd resins are an important type of plastics used to make paints. Cellulose plastics used to be first. They were first in 1926 but by 1940 they were last. Thermoplastics were last in 1939, but by 1945, thermoplastics were first among these four groups and now thermoplastics are away ahead of all other types. Thermoplastics are ahead of thermosetting resins in growth rate. Alkyd resins had this growth rate, which is also very high. Cellulose plastics are the least rapidly growing of all plastics. It seems as likely they won't get much bigger.

Chart 11, page 19.--This is a further breakdown of the thermoplastics, which we saw on chart 10. There are several important groups in this. There are the polyvinyls used in paint, raincoats, and shower curtains; there are the polystyrenes, which are most of the molded things you see in the 10-cent store. As of 1952 those two groups were practically the same. Both have extremely high growth rates. Since 1952, the polystyrenes have gone ahead of the polyvinyls. So the polystyrenes have the largest production of any plastics and will probably stay there for sometime.

Polyethylene is another very rapidly growing group of plastics. It has an almost vertical growth rate. In 1952 polyethylene production had reached 125 million pounds and very large production is ahead. Many new plants are under construction to make more polyethylene, and

CHART 11


PRODUCTION OF THERMOPLASTICS
TOTAL
POLYVINYLS (●)
POLYSTYRENE (o)
COUMARONE-INDENE &
PETROLEUM POLYMERS
POLYETHYLENE
POLYMETHACRYLATES
Millions of pounds
1,000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960

production will exceed 500 million pounds in a very few years. It will probably exceed a billion pounds in 10 years or so. It has very excellent properties.

The polymethacrylates (Lucite) had a bulge here during the war when it was used for bomber windows, radomes, and so on. It is pretty well leveled off now. It doesn't appear to be going up very fast.

Chart 12, page 21.--Thermosetting resins is another large group of plastics represented by phenolic resins. Phenolic is represented by the telephone set. The phenolic resins are normally dark colored--brown or black. They are very rugged plastics and have a lot of good properties. They are relatively cheap, but they haven't been able to keep up with the rapid growth rate of the thermoplastics. For many years the thermosetting resins were almost entirely phenolic. Then melamine and urea resins came into the picture. Urea resins are substitutes for phenolic resins in many uses. Many radio cabinets are made of urea resins. They can be white or ivory. A radio set with an ivory cabinet is probably urea. Melamine resins are similar to urea resins but stronger--also more expensive. Melamine is being used a lot to make beautiful dishes. There are many other applications. It is very strong and resistant to heat, but is a little more expensive than some of the other plastics.

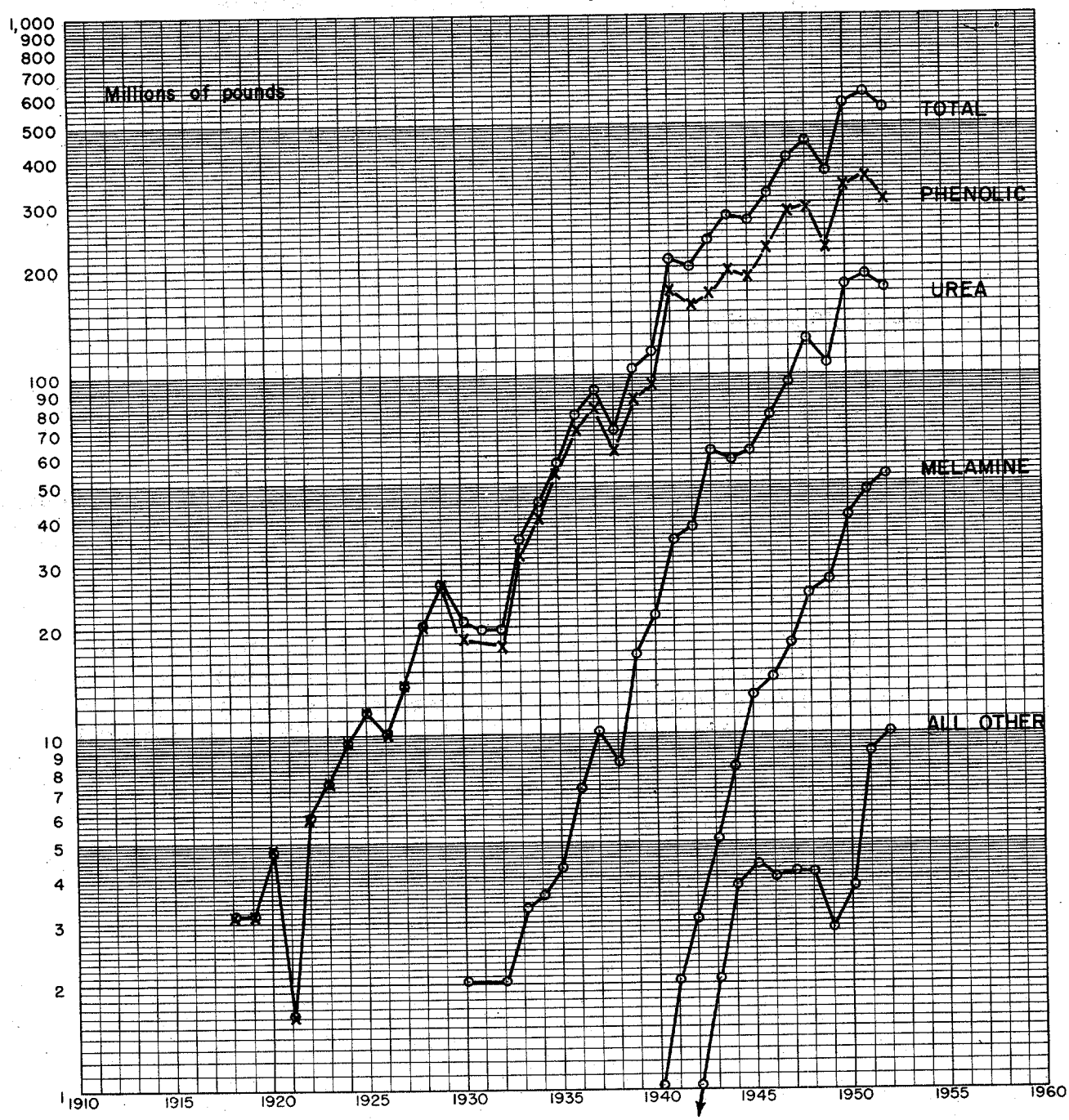
Another thermosetting group is made up of the polyesters which you have undoubtedly heard about. This is a polyester--glass fiber plastic which is used to make automobile bodies. It is also used to make small boats, I understand, up to about 35 or 40 feet, torpedo boats and other specialized boats up to about that size. It has many other uses. It is a thermosetting resin, reinforced normally with glass fibers which gives it its high strength. The only thing that keeps it from being a large business is that it is quite expensive, 50 or 60 cents a pound. You can see the high growth rate in the past few years. It is beginning to go places. You will hear more about it as the years go by.

Outline on page 22 shows the areas of competition of plastics--why our plastics are important to us--in both peacetime and wartime. First, we will divide plastics into three principal groups, rigid plastics, nonrigid plastics, and coating plastics. The latter are used to make paint. The difference between rigid and nonrigid plastics is that the rigid plastic is represented by a telephone set or radio cabinet, something with a rigid structure; whereas the nonrigid plastics are in the form of film, such as shower curtains, raincoats, or the squeeze bottles they sell in drug stores; it is flexible.

CHART 12

PRODUCTION OF THERMOSETTING RESINS

(Other than alkyds)



Areas of competition of synthetic plastics

Rigid plastics

Polystyrene	)	(Steel
Polyvinyls	)	(Cast iron
Acrylics (Lucite)	)	(Wood
Nylon	)	(Copper and brass
Phenolics	) replace	(Zinc alloys
Urea-formaldehyde	)	(Nickel and monel
Melamine-formaldehyde	)	(Aluminum
Polyesters	)	(Magnesium
Cellulose esters	)	(Glass
		(Ceramics

Nonrigid plastics

Polyethylene	)	(Rubber
Polyvinyls	)	(Leather
Cellophane	) replace	(Textiles
Cellulose esters	)	(Paper
Mylar	)	(Metal foils and sheets

Coating plastics

Alkyds	)	(Natural resins
Rosin esters	)	(Shellac
Urea-formaldehyde	) replace	(Drying oils
Melamine-formaldehyde	)	(Tin (in coatings)
Polyvinyls	)	(
Polystyrene and copolymers	)	(
Coumarone-indene	)	(
Cellulose esters	)	(
Styrene copolymers	)	(
Silicones	)	(

First, there is a group of rigid plastics. I have mentioned polystyrene before. It is the largest group of all plastics. Phonolics are polyesters in rigid form. One of the most significant rigid plastics is nylon. Most people think of nylon only as a fiber, but actually it is a plastic too. Nylon plastic is the nearest substitute for metal. It has many uses. Brass can be replaced by molded nylon, gears for example. Many gears are made of molded nylon. Nylon can be molded to a ten-thousandths of an inch tolerance, is extremely strong, and has a self-lubricating property. Nylon plastic is a bigger product than many people think--20 to 30 million pounds a year. These rigid plastics can be used as substitutes for steel, cast iron, wood, copper and brass, zinc alloys, nickel, aluminum, magnesium, glass, and even ceramics.

This possibility of replacement here has some very important implications for both peace and war. Copper, lead, and zinc are getting scarcer and scarcer as the years go by. They are gradually going up in price, although they have their ups and downs. Even steel is getting harder to get and higher in price. Aluminum has maintained a pretty good price stability and its raw materials are quite widespread; so aluminum is also a very good bet for the future. But some of these metals, at least, are getting scarcer and higher priced and they can be replaced in many uses by these plastics. Many more plastics are beyond the horizon and in the next few years they will act as replacements of metals.

The principal theme song of the Paley Report is the growing scarcity of many of these materials, particularly copper, zinc, and lead. Yet we have these plastics made from not inexhaustible raw materials but fairly plentiful raw materials. When we run out of petroleum and natural gas, we may use coal and when that becomes scarce, we can use sawdust or anything that has carbon in it.

The second part shows the nonrigid plastics--polyvinyls, polyethylene, cellophane, cellulose esters in film form, and mylar, the film form of dacron. These plastics can replace the following materials: rubber, leather, textiles, paper, metal foils and sheets. While these are not things that are particularly pressing as regards shortage of supply and increase in price, at least it is comforting to know that if these things were short they can be replaced by these synthetic materials.

Third, turning to coating plastics, we have alkyds, rosin esters, urea-formaldehyde, melamine-formaldehyde, polyvinyls, polystyrenes and copolymers, coumarone-indene, cellulose esters, styrene copolymers, and silicones. These plastics have largely replaced natural

products such as natural resins, varnish resins, and have partly replaced drying oils. They still use some drying oils to make paint but the necessity has been cut a good deal by the use of plastics. Finally, plastic coatings can to a large extent replace tin-coated cans.

Chart 13, page 25.--This chart points up the competitive nature of plastics with these other structural materials. I use the term "structural materials" not as materials to make bridges and houses but as material which is used to make things in general, whether an ash tray in the house or a gear in a piece of machinery.

This is a chart showing the growth rate of various structural materials in terms of volume--not weight but volume; billions of cubic inches, converted from weight to volume by a density factor. Wood is first; steel is the second largest; glass, the third largest; cast iron; rubber; leather; and finally we come down to plastics. They are the black dots.

Plastics have a very high growth rate. As a matter of fact, if we extrapolate its vast growth rate, you would conclude that plastics would probably exceed rubber and cast iron within the next 5 or 6 years; maybe within 10 years they would exceed glass; in 20 to 25 years, they would even exceed steel as a structural material. This high growth rate of plastics obviously can't be continued indefinitely, but it has had this growth rate for about 28 or 30 years and nobody can tell when it is going to start declining. However, sometimes that growth rate has to slow down. At least if it does continue this growth rate for a few more years, it may get up into third or fourth place as to volume of material used.

Chart 14, page 26.--This chart points up the competitive nature of these materials with respect to price. Price determines almost everything in peacetime, and even in wartime it is an important factor. This compares the cost of making anything out of these various materials. The plastics are all in dark bars, and they have all been converted to cents per cubic inch. If you want an ash tray, an automobile body, anything you want to make out of something, you have your choice--shall I make it out of steel, wood, brass, or plastic? This points up the cost quite clearly of making something out of the various materials.

Of all these materials listed here, copper is the most expensive; lead is next. Nylon plastic is cheaper than either copper or lead although it is still fairly expensive--on the order of six or seven cents per cubic inch. Then it drops down quite a lot for zinc; leather is about the same. Lucite plastic, which is considered a fairly expensive plastic,

CHART 13

CONSUMPTION OF PLASTICS VS. COMPETITIVE MATERIALS

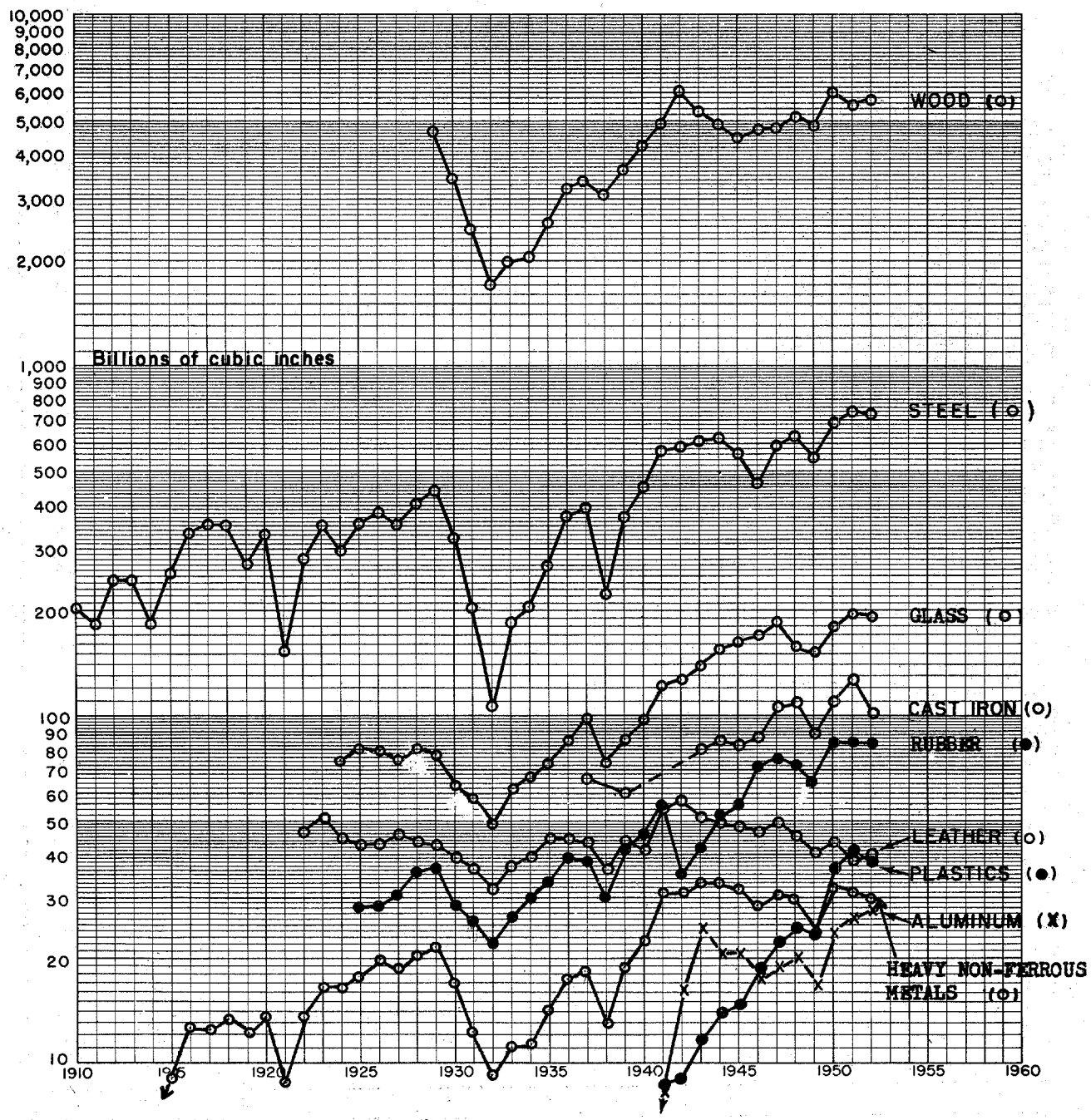
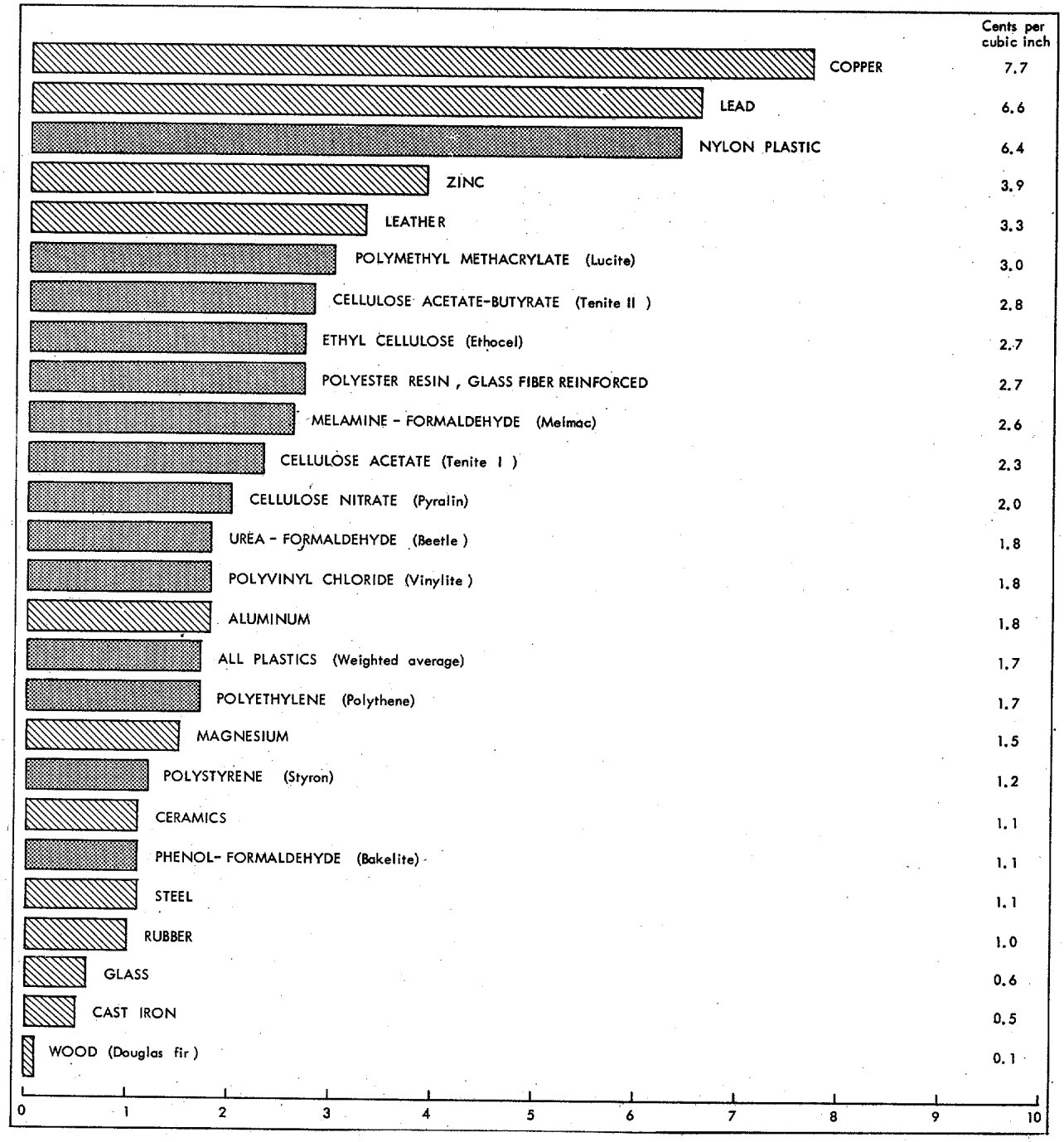


CHART 14

PRICES OF PLASTICS AND COMPETITIVE MATERIALS (1952)



yet is cheaper than either lead or zinc and these others. Nylon, as I mentioned, is replacing many metals, particularly brass and zinc for die castings, for making gears, and other parts of machinery. It has the quality of metal in terms of strength and resistance to wear. Nylon normally is a little cheaper than copper or brass, considering brass as a combination of copper and zinc. Making gears and other parts of nylon saves an enormous amount in machining cost because you can mold it to a close tolerance without going through machining operations as you do with brass.

Continuing down the chart other materials are cellulosics, polyester resin--the glass-fiber reinforced type of resin out of which you make automobile bodies, boats, and many other products--melamine-formaldehyde, additional cellulosics, urea-formaldehyde, polyvinyl chloride, aluminum, polyethylene, and magnesium. Polystyrene and phenolic resins are the two cheapest resins. They are getting down to where they appear to be the same average price as ceramics; almost the same as steel. In other words if you want to make a product out of polystyrene or steel, on a volume basis, they are practically a standoff.

Rubber is cheaper; glass, cheaper; cast iron, cheaper; and wood, by all odds, is the cheapest of all structural materials. This chart is quite significant from either a peacetime or a military point of view. This shows the relative cost of making products out of plastics. There is some degree of comfort in knowing that, if we need to, we can substitute plastics for some of these scarce raw materials.

I appreciate the opportunity of speaking to the student body of the Industrial College and thank you for your attention.

QUESTION: In speaking of the use of petroleum in making petrochemicals and in giving us several formulas, you mentioned several additives during the process, such as hydrochloric acid. What percentage of the end product, either by weight or volume, or something, is actually petroleum? In other words how much do you add in proportion to the petroleum that you use, as a round number?

MR. EWELL: Of course, oxygen enters into many of these products as an additive; chlorine enters into many of them. I would say probably, as a general average, that, of this whole mass of petrochemicals, probably on the order of two-thirds of the weight of a molecule originally came from petroleum and natural gas and maybe the other third came from various additives.

QUESTION: One of the problems that the military has in the wartime application of these plastics to our needs is the fact that we have to operate under conditions much more severe than those under which the civilians operate. To what extent are these new plastics being adapted to military needs? Do you know how far the military is going and how far industry is going in meeting our very rigid requirements?

MR. EWELL: Well, certainly, I suppose nowadays that industry isn't doing too much in the way of trying to meet military applications except on special request. After all, peacetime applications are uppermost in their minds right now. However, there are many plastics which are not used for particular purposes in a peace economy today because they are too expensive. For instance, many things that could be made of molded nylon are not made of nylon because it costs too much. But that plastic might meet military requirements and if the price were not the primary objective, then nylon could be used for many purposes where it couldn't be used in peacetime. On the other hand if there were pressing problems in the military application of plastics, I am sure that every chemical company would want to do something on them if they were requested to do so. In fact, I think, from my experience, most of the big chemical companies are so anxious to find new markets for their products, military or otherwise, that if they were acquainted with an important need of a certain specification that they would work on it with their own funds. They would certainly work on it if the Armed Forces would finance them on it. But I think in most cases they would work on it with their own funds anyway if they were well acquainted with the need.

QUESTION: Doctor, do the figures you show on the consumption of petroleum by the chemical industry indicate the fact that some of the chemicals and some of the plastics are actually byproducts and would not be otherwise consumed if plastics were not made out of them?

MR. EWELL: Yes, to a considerable extent these petrochemicals are made roughly fifty-fifty out of natural gas and petroleum. Now in the case of natural gas, it is really a competitive use because you can use natural gas to make petrochemicals or you can use it for fuel or carbon black. There is competition.

However, in the petroleum field, it is true the raw materials used to make petrochemicals are substantially byproducts from petroleum refining operations, for example, ethylene, which is the largest petrochemical.

However, most of the ethylene in the United States resulting from petroleum cracking is used for fuel. At one of the largest refineries

in the country, at Lake Charles, Louisiana, at which I believe they make 2,500 barrels of ethylene per day as a result of cracking operations, they burn it for fuel. So there is some room for expansion there. But it is a regional matter. In the south-western area, they pretty much use all the byproducts. But in the Philadelphia, Los Angeles, and Chicago areas, which are large petroleum refining areas, they don't use these byproducts because the industry is not there.

QUESTION: Doctor, to what extent, if any, does the National Science Foundation sponsor plastics research?

MR. EWELL: We don't sponsor plastics research at all. We sponsor only basic research at the Foundation. If research has any definite practical application, we don't sponsor it.

QUESTION: In your talk you spoke about using petroleum as a raw material. If in the future we went into coal or sawdust, as you mentioned, how much of a problem would there be in plant conversion? Could you use the same factories you have now or would the plant have to be different?

MR. EWELL: It wouldn't have to be entirely changed--only partially. Say that you started with coal or sawdust and converted to ethylene, the plant where it takes up ethylene as the intermediate which enters into the end product would still be usable, but the forward part of the plant where you convert the original material into ethylene would have to be entirely replaced probably.

QUESTION: If I interpreted your charts correctly, you treat synthetic fibers, for example, separately from plastics. In some reading I have done, it appears that the plastics industries at least would like to call all synthetics plastics.

MR. EWELL: They all are really plastics, or, using even a broader term, they are all polymers. Plastic fibers, synthetic rubber, all are polymers. Calling them all plastics would be stretching the use of the term plastics, but they certainly are all polymers.

QUESTION: I wonder how close we are to the plastic body in automobile manufacture. Would you comment on that, please?

MR. EWELL: I suppose General Motors would be in a lot better position to answer that than I would. At least, it is a fact that General

Motors is making some 5,000 or 10,000 Chevrolets this year with plastic bodies. I don't suppose there is an automobile manufacturer that hasn't some plastic bodies in the experimental stage. There have been a number of specialized sport cars made with plastic bodies, both in this country and in Europe. Just what the economics of it are, I don't know. So far as materials go, the plastic body costs a little more than the steel body, but fabrication costs may be reduced which may reduce the cost substantially, although I think the plastic body is still more expensive than the steel body, even after fabrication and the various other things that add to its value--appearance, repair ability, and that sort of thing.

CAPTAIN HALE: Pursuing this, on fabrication tooling, what is the cost of tooling up for a plastic product versus a metal-type product, and the skills required?

MR. EWELL: I am not really qualified to answer that. I just don't know. Plastic molding compares fairly closely with die casting. It is pretty much the same sort of thing. But I am just not qualified to answer that question broadly.

QUESTION: In a first-line automobile tire, how much, if any, natural rubber is required?

MR. EWELL: It is my understanding that all automobile tires today are made principally out of synthetic rubber. There is still some natural rubber in them. The last figure I heard was 70 to 30.

QUESTION: Is natural rubber required?

MR. EWELL: No, I am sure tires could be made out of synthetic rubber. I have no doubt many tires on the market in the last few years have been made entirely of synthetic rubber. What the situation is, I don't know for sure.

There is a very important point which that reminds me of--that is, synthetic products have the inside track over natural products. In natural products, you are stuck with the structure. You can't do much about the natural fibers with respect to structure. You have to work on the structure of it without destroying the molecule. With synthetic products, there is an infinite possibility of improvement. Most important, whether it is synthetic rubber, plastics, or fibers, you can bet your bottom dollar in 5 years, the product will be better; in 10

years, still better; 20 years, still better; and cheaper at the same time. So whatever generalization you make about synthetic versus natural products, five years later the balance will be tipped more in favor of synthetic products. Sooner or later most natural products will be run out of business by synthetic products.

QUESTION: In selecting an economic plant location, why did they select Illinois rather than where they are burning natural gas as a waste product?

MR. EWELL: I don't know where natural gas is burned as a waste product any more. That is pretty much a thing of the past. There is a problem as to whether you put your plant in Texas and ship your product to the East or build your plants in the East and team up with somebody who has a pipeline to the East. The philosophy of the plant in Illinois is that, since the market is Chicago, Detroit, and Cleveland, why not put the plant up there and ship the gas by cheap pipeline to the plant rather than ship the finished products by tank car from Texas. That was the philosophy of it. Just how it will work out, I don't know. As a matter of fact, National Distillers did just that. It teamed up with the Eastern Panhandle Pipeline Company and set up this petrochemical plant.

QUESTION: Does that company expect seasonal variation in its production? Does it produce more in the summer when prices are lower for natural gas?

MR. EWELL: I don't know what the plans are. It would appear to be the logical procedure if it could change the output of the plant without actually shutting the plant down. It is expensive to shut a chemical plant down. It might put production down 25 or 30 percent and still keep the plant operating.

MR. BAUM: Dr. Ewell, I thank you on behalf of the Commandant and the student body for a very interesting lecture and a very fine question period.

(26 Mar 1954--250)S/ibc

E59700