SCIENCE AND NATIONAL POWER

2 November 1955

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Mr. John Carlton Ward, Jr., President, Vitro Corporation of America was born in Brooklyn, New York, 21 January 1893. He attended Cornell University, receiving the M.E. degree in 1914. He was appointed to the position of development engineer, International Paper Company, 1914; became assistant to the works manager, Niles Tool Works Division, Niles-Bement-Pond Company in 1915. In 1918 he was appointed production engineer, United States Ordnance Department, Watervliet Arsenal. In 1919 Mr. Ward became works manager, Pratt and Whitney Division, Niles-Bement-Pond Company. In 1926 he was appointed vice president and general manager of the Hartford Machine Screw Company. During the period 1929-1934, he was general works manager of the General Cable Corporation; was named vice president of the Rome Company, Inc., in 1934; served as vice president, general manager, and director of the Pratt and Whitney Aircraft Division, United Aircraft Corporation from 1935 to 1940; became president of the Fairchild Engine and Airplane Corporation, 1940; and in the period 1948-1949 served as chairman of the board of that corporation. He is a director of the Holyoke Wire and Cable Corporation and the Fiber Can Machinery Development Corporation. In 1942 he was appointed member of the War Production Board Mission to Great Britain, and is a member of the Engineering Council, Cornell University, the Newcomen Society, the Society of Automotive Engineers, the American Ordnance Association, and the Institute of Aeronautical Sciences. Mr. Ward has written many papers and articles on technical engineering subjects. He is a member of the Board of Advisers of the Industrial College of the Armed Forces.

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GENERAL HOLLIS: Admiral Wooldridge, Distinguished Guests, Gentlemen: This morning marks the tenth appearance on this platform of one of the old friends of the Industrial College, Mr. J. Carlton Ward, Jr. He made his first talk here in 1946 when I was a student, and I still remember that dynamic lecture with much pleasure.

He is, as you have seen from his biography, a man of much versatility and many talents, and in his day he has been an officer or director of a large number of corporations. He is an engineer and an author of note. He has been a public servant and has served the Federal Government in many capacities on commissions and boards.

In addition to that, he has one other achievement of which he is very proud, which would probably leave Captain Ross or Captain Keats or myself cold. As a member of the Board of Trustees of Cornell University, he succeeded, in the course of the erection of a new dormitory for students, in assuring that all the bunks were made seven feet long.

It is a privilege for me to be able to present to the Class of 1956, Mr. J. Carlton Ward, Jr.

MR. WARD: Well, I have enjoyed my last applause. I'll explain that remark later on today. As a matter of fact I wrote this lecture this morning and I am following the scope that has been assigned, and which I am going to read to you. You gentlemen have your own problems to solve, so I thought you might be interested in the one we have to solve this morning from this platform:

> "Science and National Power. The potentiality of research as shown by such accomplishments as the creation of atomic energy; the general effects of scientific development on engineering and industry; the effects of science on the conduct of war; and the maintenance of the relative technological strength of the United States."

Probably you will not get out of here on time. As military men you are prepared to take it, I know, and on that assumption, we are going to take an imagination-stretching exercise here this morning.

We have something on the order of 20 charts or slides here and, if the old Chinese proverb with which you are all familiar is true, meaning that one picture is worth 10,000 words, you are in for at least 200,000 words, plus. These charts have been prepared in part by the faculty here, and in part by other sources, which I will try to indicate to you as you see them.

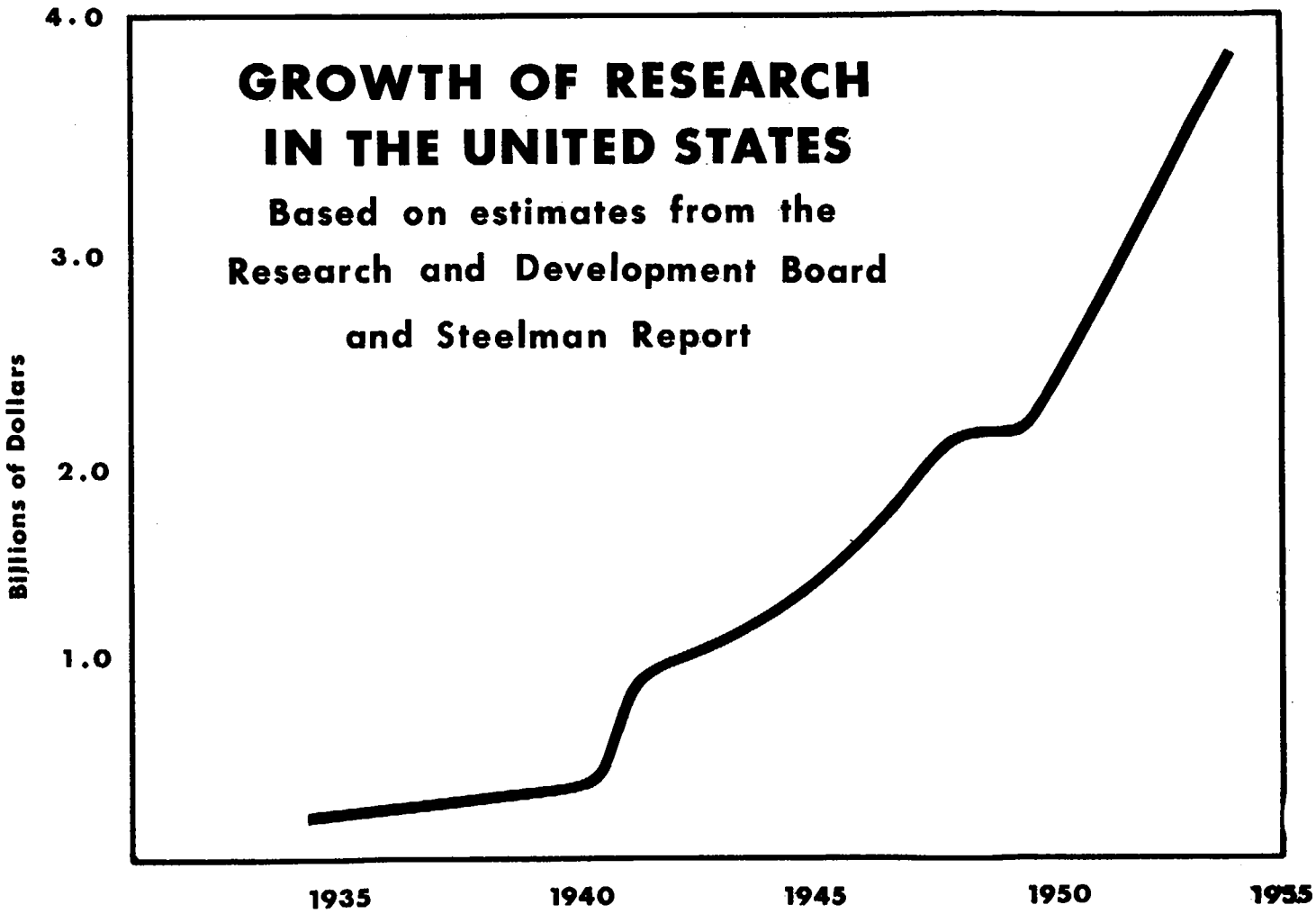
I shall make one more remark and then plunge into this problem. Some few years ago the trade association of the fertilizer manufacturers were having an annual meeting. They had decided prior to that meeting that they would forego the usual custom of having a so-called "name" speaker. Sometimes the boys, as a result of the preparatory exercises before the dinner, were in no position to appreciate some of the speakers that came before them. So they said, "Let's try one of our own executives." They selected a vice president of one of the leading fertilizer companies. He was duly introduced after the dinner had been consumed, but not digested, and the secretary of the association introduced him in this fashion: "Well, boys, this year we have a new approach to our convention and our speaker is one of our own executives. He needs no introduction to this group. He is going to speak on the subject of humus fertilizer. Believe me, gentlemen, he is full of his subject."

So let's start right in and follow the scope of our lecture. With no more introduction, we will have the charts.

Chart 1, page 3.--Gentlemen, there is a complete lecture in this one slide--an innocent looking wiggly line. This chart cannot go back before the birth of research in America, which was in the year 1903. You men form a very distinguished class and I understand that you have many experts in the field of research and development. I would ask those who are familiar with some of these facts, to bear with me, because I think that every citizen of the United States who is interested in our future security should perhaps understand the amazing implications of this little black line.

It was in 1903 that the General Electric Company organized the first research laboratory in modern science in the United States. I was

CHART 1



SOURCE: *Industrial College of the Armed Forces.*

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told that it consisted of three scientists. Up to that time we had lived in an age of invention. We will not pause to define here the difference between invention and research; but they are quite different processes, even though at times they lead to somewhat similar results. Thomas A. Edison, as you all recognize, was probably the greatest example of the inventor.

If this curve were to go back to 1903 it would have practically no significance on this scale, but it would have real significance if we had the time to trace it back on a different scale. Research in the United States was considered to be at that time a very minor part of the economy of the country, and indeed it was until we hit the impact of World War I.

At that point America suddenly found itself devoid of many of the essentials of its economy. Many necessary imports had come from Germany, which, despite being a nation of poor natural resources and limited manpower, had become one of the great powers of the world, without colonies such as the British, Dutch, and French empires possessed. The Germans had done it solely on the recognition of what we and many other nations had failed to see, the significance of the role of research.

Out of their research they built the great synthetic chemical industry which allowed them to overcome such British monopolies as the production of indigo and such as the Japanese monopoly in camphor. They successfully solved such problems by using very simple raw materials and by adopting--this is the point, gentlemen--by exploiting synthetic chemical processes resulting from the scientific discoveries made largely in the pure science atmosphere of French and British research laboratories.

This in itself was a revealing discernment of how a nation of "doers" took ideas, harnessed them, and with very poor natural resources economically became strong enough to be a threat to world peace.

The lack of these products which we had been importing from Germany caused by the embargoes of World War I brought home to America the need for similar new products and processes and resulted in a sharp increase in the function of organized research and development. If chart 1 were traced back to 1903 on a different scale, it would show this effect quite clearly.

Now, however, between World War I and World War II, research and development remained a relatively minor function in terms of our total effort in the American economy. And now let's look at World War II. At that point on the chart, you see again the recognition and response under conditions of stress when we went to work to stimulate our research capabilities.

I hope you will notice that after the conclusion of World War II research activity did not immediately recede. We can notice that before Korea it again began to level off. In the impact of the Korean incident our curve took off like a modern dream of an intercontinental ballistic missile, and we are still going into the stratosphere. We are on a 4 to 5 billion dollar basis today. And remember, a dollar for research includes a minimum of material, a minimum of profit; and therefore, as a percentage of national effort expressed in such a curve, it is somewhat unique. It is unique in two directions, in the character of the people who perform the function, and in the profound and lasting importance of its contribution.

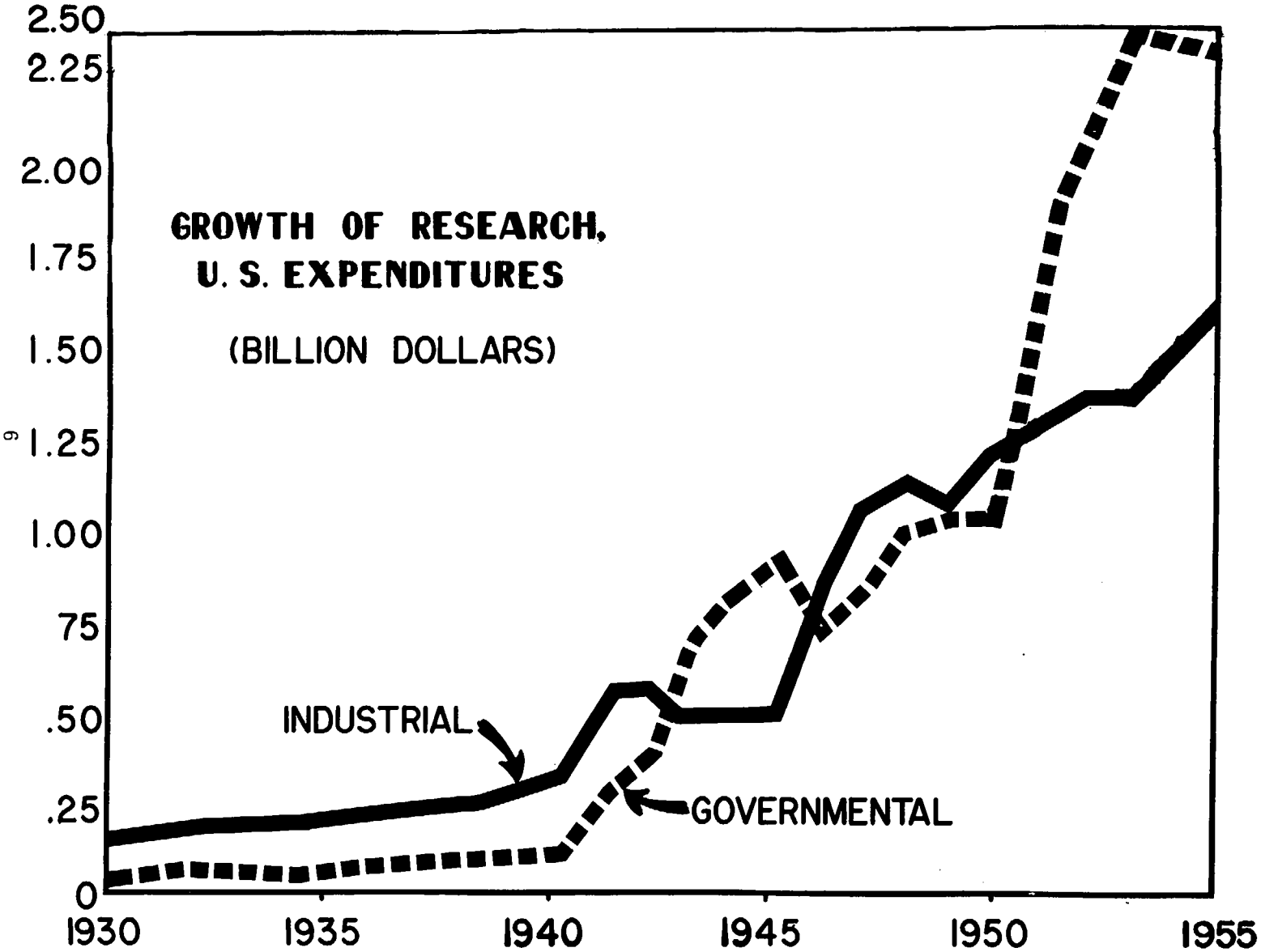
Chart 2, page 6.--The curve in chart 2 is to show you quickly the relation of governmental funds for research versus the industrially appropriated funds.

If you will notice, prior to World War II, even with the efforts of the Department of Agriculture, the Bureau of Standards, the National Advisory Committee for Aeronautics, and the great governmental laboratories, the total for Government research was low compared with that for industrial research.

You will notice the impact of war. Both responded. You will notice the total for government research for the first time crossing the line of industrial research effort, and you see it took off at an increasing rate, until "bring the boys home for Christmas" hit appropriations by Government, and then there began an immediate recession.

I would like to dwell a little bit on the impact of this political atmosphere on the Congress. I happened to be a representative of the aircraft industry right after World War II and helped to present to Congress the importance of continued research for the national defense. It was entirely out of "ad lib" testimony that, when asked to give an example, I trotted out my concept, thought out on the spur of the moment, in those "sacred" halls, of the technical need for propelling airplanes with atomic energy.

CHART 2



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Within a year I found myself saddled with what quickly became a very unpopular project, "Nuclear Energy for the Propulsion of Aircraft," known as NEPA. It took more than half my business time and effort and five years to prove to the atomic authorities that such a concept was sound, the vindication finally resulting from the security-classified Lexington Report. This report, which was submitted by Dr. Walter G. Whitman of M.I.T., as chairman, represented the work of more than 40 scientists and engineers who reviewed NEPA, and who were unassociated with the project. You know now that this project has a number one priority in our present defense program.

I am mentioning this, not because of any effect my own efforts had, but because I know intimately the course that the project took, and it may persuade you perhaps to concentrate a little bit on how such ideas can be born, and the dreadful process they have to go through before they become popularly accepted, particularly if they cut across the inertia of whatever is the current effort.

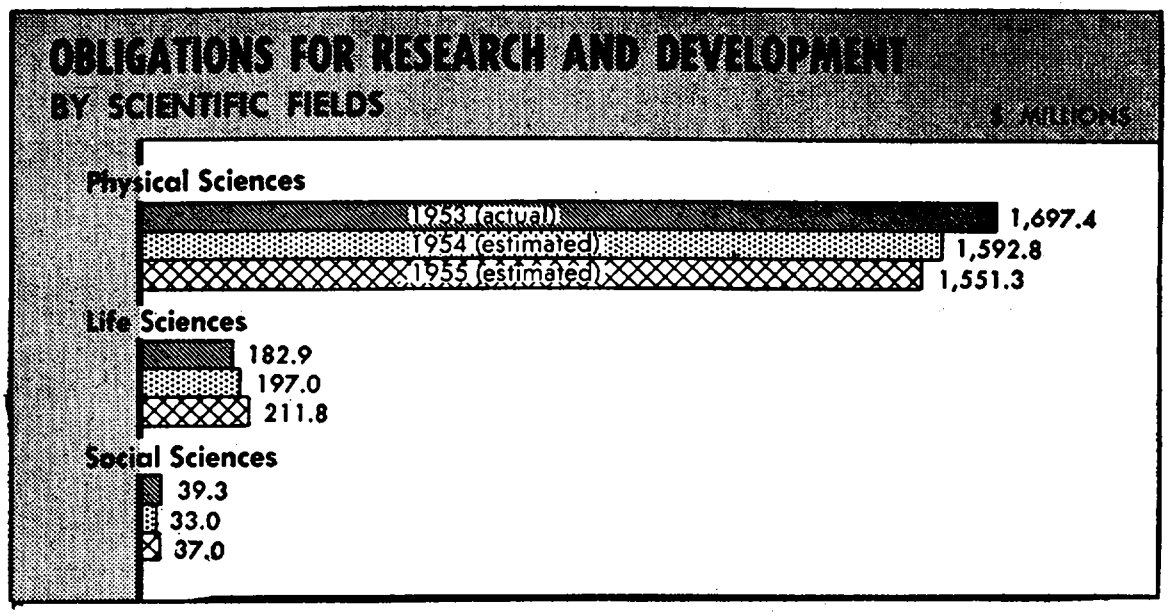
At any rate, you will notice that at the end of the war the Government-sponsored research effort sagged, but you will notice that the corresponding industrial effort did not. This was a recognition on the part of free enterprise, not subject to the pressures of politics, that here lay the great key for the future of our business economy; and there was a general adoption of research as a necessary tool. I will try to show you a little later in these pictures the missing element that was not fully recognized in this extraordinary response.

Again please notice that it was not until the Korean War threat that Government-sponsored research overtook the research that emanates from free industry.

Chart 3, page 8.--This chart is very significant. It shows the main areas, the formal areas, of research effort, and you will notice that the physical sciences far outstrip the life sciences and the social sciences.

Without in any way casting aspersions on the social sciences, I want to say they are not actually sciences. They deal with incommensurate material not with commensurate material which is the foundation stone of the natural sciences. If you can't measure a thing, you can't truly understand it in a natural science. We talk about the average man and talk about the constant dollar. These "things" do not exist and

CHART 3



Source: National Science Foundation.

cannot be exactly measured. It has been said that if you laid all the economists end to end, dealing in statistics as they do, they would reach no conclusion.

Now, gentlemen, don't underrate the economists. They are a necessary adjunct and perform a useful function. But don't do them the unwarranted honor of ascribing to them more than they have the power to do. When they deal with the "average man" they are dealing with a mythical concept; and when they take the law of supply and demand and, as they think they did under one national administration, suspend it, they are out of the field of actuality. You can't do that with a real scientific law like the law of gravitation. Herein lies an essential difference.

There is something else I want to point out. In the social sciences which are vital and important to your mission in this Industrial College, and with which you must be, to a certain extent, familiar and to which you must be dedicated, there are those who are trying to apply scientific techniques to unscientific and incommensurable material. That may be good; but it must not fool you into believing that the end conclusion is a scientific conclusion. They may reach commonsense conclusions by the best method known, from a mass of data which at times are too complex for any human mind, or even one of Norbert Wiener's cybernetical machines. However, this is not a true "scientific" process!

The life sciences, on the other hand, are very vital. These are agriculture, biology, medicine, and allied fields. They concern your health, your food supplies, and much of the Nation's economic potential in agriculture and its allied fields.

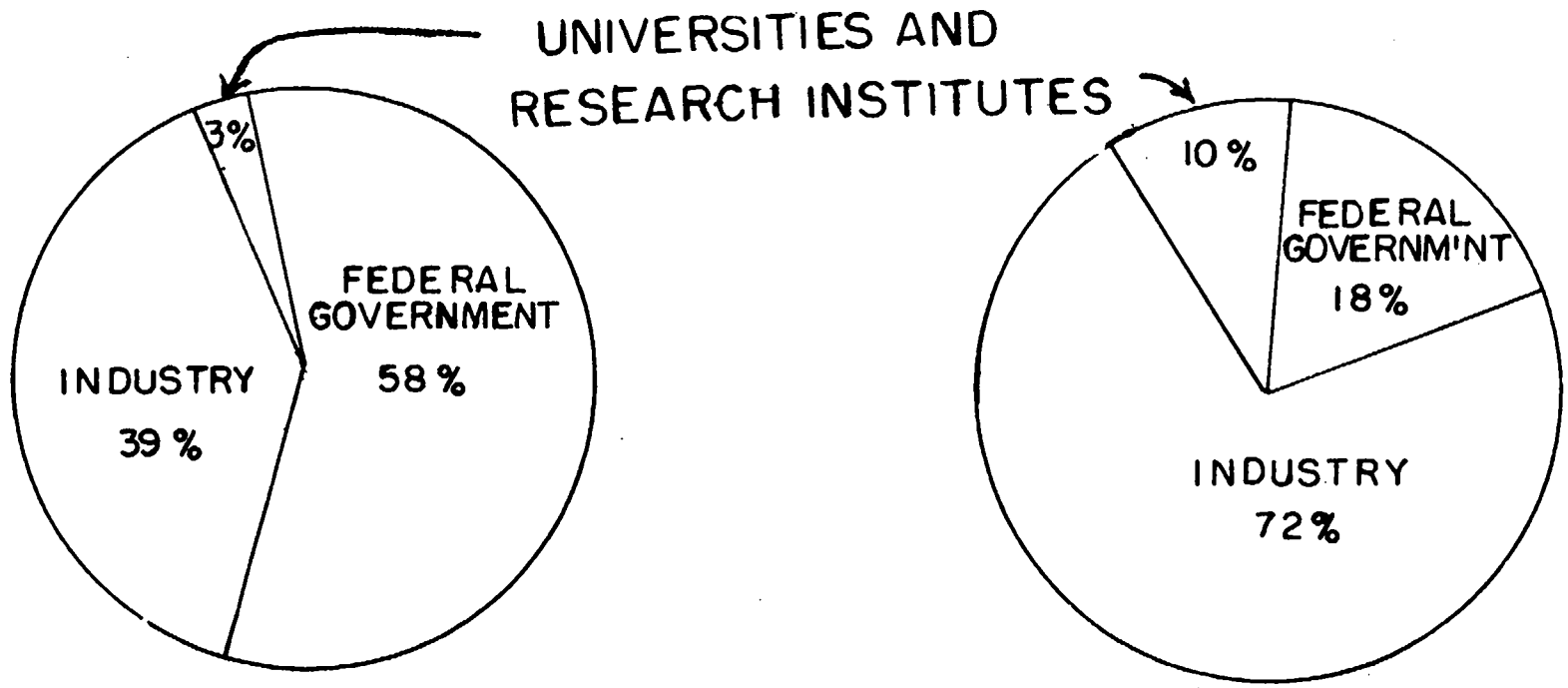
Since the life sciences do not require the elaborate hardware that is a part of the physical sciences for their research and development phases, the chart somewhat distorts the comparison as a measure of the relative effort. This could also be said of the social sciences which require even less in the way of laboratories and instruments than do the life sciences and which, for the most part, work with pencils and paper and national statistics.

Chart 4, page 10.--On the left of chart 4 you see where the money for research and development comes from. Good old Uncle Sam, we taxpayers, put in 58 percent of the dough in the year 1955. Industry throws in 39 percent--at least that's what the chart says. Some of

CHART 4

SPENDING FOR RESEARCH & DEVELOPMENT

FOR THE YEAR 1955



WHERE THE MONEY COMES FROM

WHERE IT IS SPENT

industry's contribution, of course, flows indirectly from Government through supporting Government supply contracts.

The 3 percent funds which you see under the classification of universities and research institutions is an extremely vital and major component. It is limited because it comes out of nonprofit institutions and consequent limited resources. Underneath this fact is a very subtle principle because this 3 percent is probably more important for the long-range implications than all of the remaining 97 percent. You see it deals with the enlargement of man's fundamental knowledge of the forces of the universe and his environment. In the course of the lecture, we will try to develop this further.

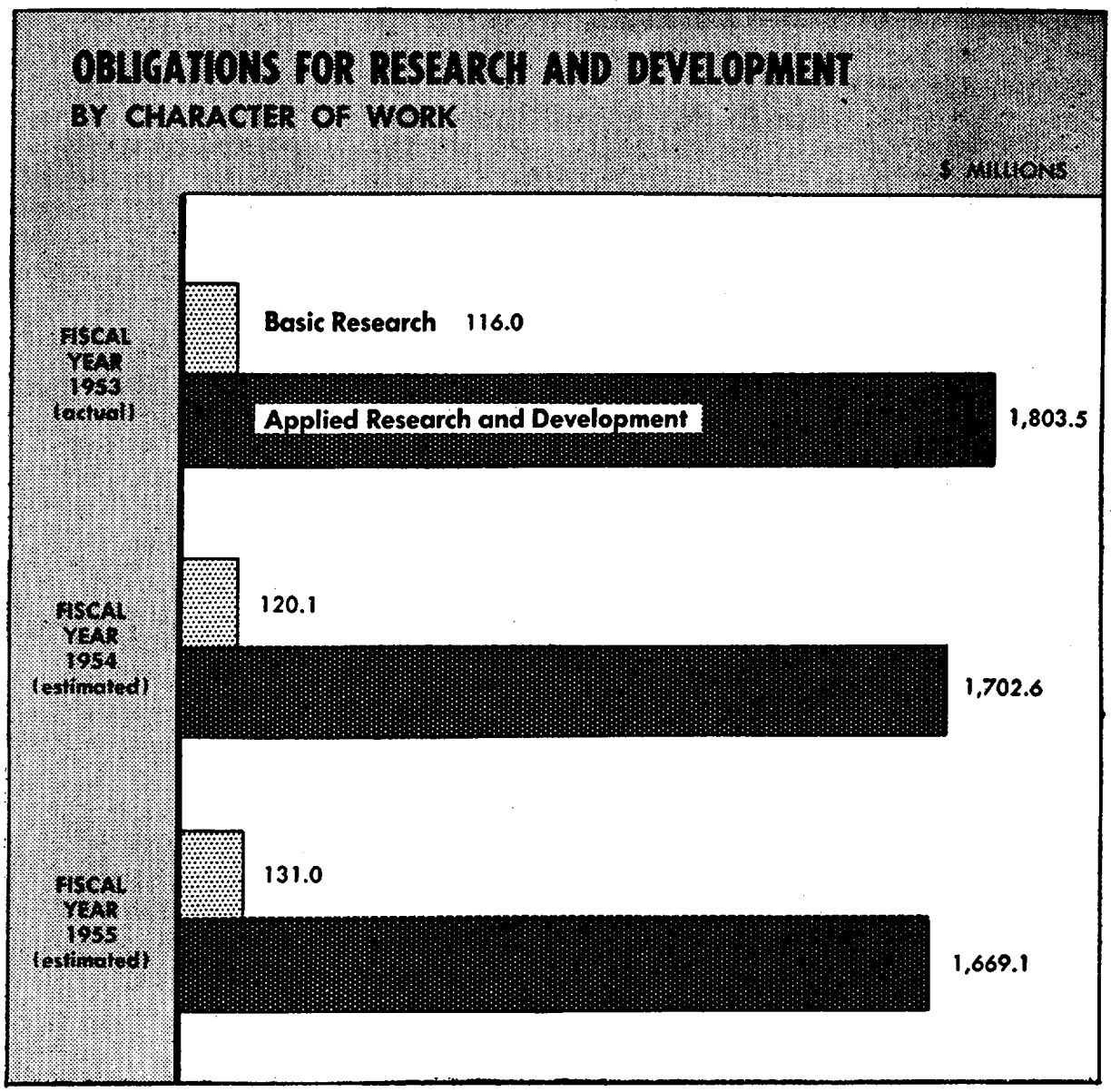
At the right of the chart on the side of performance, you see that the universities and other institutions perform 10 percent of the research. Obviously the money flows to them from industry and the Government. Also you will see that the Government performs only 18 percent, relying on industry as its agent, which is proper in our type of economy. We are going to come back, later, to the significance of this 3 percent and the 10 percent.

Chart 5, page 12.--Let's look at chart 5. What is basic research and what is applied research and development? We are going to have to unmask some fellow members of industry, of which, of course, I am a member, and tell you that we talk about research and development in a very loose fashion. Those of you here today who are Ph.D's in the natural sciences do not have to be told of the implications of what I am trying to say to this audience.

There are very few industrial organizations in the United States that do anything approaching basic research. This is almost entirely the area of the 3 percent university contribution. Yet some universities do applied research, some to an extent that worries educators as it can detract from the educational process. Indeed it can be a real danger. In the desire to get financial support, endowed schools and universities will take applied research contracts to help them meet the need for improved salaries for professors.

Endowed education, free of political interference, sets the standards in America. It is doubtful if it can continue to exist without greater financial support, and applied research contracts have been an indirect means for such support, and therefore, present great temptations to the educational administrator.

CHART 5



Source: National Science Foundation.

However, this is not our subject, except that it does concern you as military officers and procurement officers in the military departments. It would be a great tragedy to start making commercial research laboratories out of great teaching institutions. And remember, it is a very tempting thing for them.

Basic research which you see indicated in chart 5 can be illustrated by one of the items of the scope of this lecture. We cannot do full justice to it here, but I would like to leave you with some impressions.

As an example, where did atomic science, as it is practiced today in your weaponry and in the peaceful or industrial atom, come from? Who discovered it? There is no perfect starting point for such an answer. We can begin in 1890 with Dr. Heinrich Hertz, a German, who produced the concept of electromagnetic waves in space. In 1895 he was followed by Dr. Wilhelm Roentgen, another German, who produced X-rays, which, as you know, were high-energy electromagnetic waves in space. In the following year, a Frenchman, Dr. Antoine Becquerel, introduced the concept of radioactivity. One year following him came Dr. J. J. Thomson of England, who isolated, discovered, and measured the electron; and for the first time the behavior of so-called chemical elements began to yield to the analytical process of expanding scientific knowledge.

The year following him the Curies, a Polish woman and her French husband, isolated radium, and for the first time studied the laws of radiation. Two years later a great German mathematician, working with paper and pencils, produced an outstanding concept, without which there could be no atomic science. He proved that energy occurs in particles, specific particles, and that the particle of energy, a constant known as "h" (Planck's Constant) is measurable and is fundamental in nature, cannot be changed, and is as precisely definable in mathematical terms as pi. That man was Max Planck, and he shook the scientific world, because he did away with the concept that energy was something that occurred in a stream and that could be cut at any point.

In 1905, Dr. Albert Einstein, building further on the Lorenz mathematical transformation equations and the remarkable Planck discovery, derived the mathematical concept of relativity, which is too broad to be discussed here, except in one simple form, which you find quoted over and over ad nauseam. This states that $E=mC^2$.

Now, for those of you who do not think in mathematical terms, I would just like to translate quickly this equation as I see it. We are humans, who have evolved up an evolutionary scale. If you study this process, you will realize that you are a very unfinished product and that evolution is still going on today. They say one child in each 8,000 born is supposed to have some characteristic not found in its ancestors.

This is the natural process of upgrading and evolving living forms. We, in our relatively immature form today, see the universe through very indistinct instruments--eyes that see only a minute fraction of light; ears that hear only a minute fraction of sound; hands which can feel only objects of enormous size in terms of the microcosmology. And our instruments of deduction of the universe are exceedingly imperfect. So we have built up a picture of the universe which is personal, but is not really the picture of pure science. $E=mC^2$ satisfies you, perhaps, mathematically, but you don't understand it, because it really tells you the fact that energy and matter are the same thing.

You look at your electric light bill at the end of a month and you pay for so many kilowatt-hours. Mathematically, you can express it just as accurately in pounds, kilograms, or any unit of weight or mass. Likewise you can get on your scales, or you look at your profile, and say, "What is happening to me?" You can accurately describe your condition in terms of added kilowatt-hours, British thermal units, pounds of energy, or any of the physical measurements for energy. You are at the same instant both energy and mass, because they are scientifically the same thing.

Thus the chemical elements which have been referred to classically as the fundamental building blocks of all nature, turned out to be, in the light of the new discoveries, not really fundamental. Lord Ernest Rutherford, by 1919, in his classical experiment, turned nitrogen into oxygen by bombardment with alpha radiation. The expansion of this knowledge proved that chemical elements were not fundamental in nature but can be broken down into subparticles of a still more fundamental nature.

From the Danish scientist, Dr. Niels Bohr, who produced the first picture, or anatomy, of an atom and collected the Nobel prize for it, on through the discovery of the neutron by Dr. James Chadwick, another Englishman, up to Enrico Fermi, the Italian, who gave us the first nuclear reactor--these men for the first time knowingly transmitted

and produced, from the natural forces that are around us at all times, what we call atomic energy.

Why is this point so significant? I will start with an example. When I was graduated in engineering, it took 2.5 pounds of coal to produce a kilowatt-hour by the best engineering of that time; and we thought it was good at that time. Thomas Edison started in the 1880's with 15 pounds per kilowatt-hour. Today we can produce it with a lot less than one pound of coal or its equivalent in oil or gas fuel. We have multiplied the earth's resources in the form of fossil fuels by over 300 percent in my active business life. "Tremendous," you say. Tremendous it is! The engineering profession and its science collaborators can take great credit.

Now let's suppose we bring out the concept of peaceful atomic energy generation in which form one pound of material changed into its energy component could theoretically develop 11,400,000,000 kilowatt-hours. By application of the equation, $E=mC^2$, we find that the only natural atomic fuel is U-235 and here only 1/1,000 of its mass can be converted or, roughly, over 11 million kilowatt-hours. Divide this by, roughly, three to get it in the form of electrical energy at the generator and you see the enormous import of this concept. That is not an evolution in science; it is a revolution. And it is here. That is why the atomic age is not just another scientific discovery like let us say, television. It is a revolution; and the meaning of this example can be applied to chart 5. It is in that little gray block of basic research that such ideas originated--not in that big black block of applied research and development.

Pick up any "Business Week" or "Saturday Evening Post" or "Life" and read the self-indulgent advertisements of the great corporations of America featuring research done in their laboratories.

Gentlemen, almost entirely such research lies in the applied fields. There are only a few outstanding exceptions. It is in the gray area of basic research that America has been deficient. Our economy has emerged from a pioneer state endowed with rich resources, great markets, and has created a nation of "doers." It is here that the concept of mass production originated in the friendly economic climate.

On the other hand, the true scholar, working without any field of application in mind, was put down as a "queer," and described as an

"egghead," "longhair" and other terms which are not truly endearing. In Europe, on the other hand, there is an intellectual aristocracy and such men receive the accolade of their fellow citizens. The names which we have recited in our examples of the root sources of atomic energy were without exception foreign born and educated. Many of our leading men of science in the United States today were born and educated in Europe. Thus, we talk a lot and boast about our research for which we spent more money, it is said, than all other countries of the world put together. But the fountainhead from which this effort grows still remains largely a European cultural product. This is the challenge for America and should be important to all of you as potential military leaders.

I want to pay tribute now to the Commanding Officer of the Air Research and Development Command, with whom I recently had a very interesting feet-up-on-the-desk, locked-door discussion. He recognizes that without these two types of research, basic and applied, we cannot keep ahead of the enemy. He said, "By law we can pay 15 percent profit to an industrial firm for research, but we don't. Within the Air Force we have a rule of paying 7 percent. But," he says, "this is wrong. The head of one great research organization recently came to me and said, 'We are going to have to start making things and put our research workers on "Hardware." We can't live on 7 percent and attract capital, because when we allocate our expenses, the boys come in--that is your Government accounting hounds--and say, for instance, that sales has no function in a Government-supported activity and we must disallow it for reimbursement. But if we can't sell we get no orders. We are not supposed to sell you military gentlemen, but, if we never come near you, you don't give us any orders. When we come near you, your accountants say it is sales expense, and you don't sell the Government. So out it goes.'"

I am illustrating only one problem of the matter. By the time an industrial research firm gets through with such cost disallowances, and by the time Mr. Humphrey and his aides come around and take the taxes, a research laboratory does not have even 3 percent left to finance and buy its equipment, build its laboratories and provide necessary profit. If it were not for the fact that some of you gentlemen overlook the rules occasionally, I don't think we would have nearly the research resources we now have. I want to pay tribute to such officers. You have often gone as far as you could. Sometimes, in violating your own ground rules, you have provided research laboratories with equipment by the darnedest devices I have ever had to deal with, and more power to you.

To return to the interview with General Thomas S. Power, Chief of the Air Research and Development Command. He said during the meeting that they had renewed an Air Force research contract with a leading research group as the statutory fee of 15 percent simply to avoid losing research scientists to the field of hardward development. He concluded by saying he felt that the Air Force would have to do more of this.

Confidentially, gentlemen, I hope that this thing can infect the other services in order that our true research-minded organizations may continue to stay in business and even expand. It should be clear that they cannot exist and attract capital on a 7 percent fee from which there are measurable accounting disallowances due to Government rulings, and then pay more than one-half of what is left to the Treasury in the form of taxes. What is left just will not pay dividends and persuade banking institutions and insurance companies to make loans necessary for facility development and financing.

Perhaps I should be very candid by saying that our own firm, Vitro, is directly involved in this problem as we are a research-minded organization and must deal with these problems in a very practical sense. However, the important point is that our basic research has been largely done by foreigners and we do get many of our basic ideas from Europe. I am conscious of the fact that we were the first to put a bomb together and make it work. I sincerely believe we are the best damned tinkerers in the world. We have superb engineering and processing industries to support us but do not forget that the basic ideas came from abroad and that many of the leading scientists who worked in the United States on the project were born and trained in an alien land.

Perhaps I am saying that it is up to you men to help solve this problem for the defense establishment. We do have this kind of brains here in America and it merely needs sufficient encouragement for them to go into the paths of true science and scientific development, and for our universities to be strengthened in these areas by supporting contracts which can best be done in the atmosphere of free inquiry provided by such institutions, and which is the climate that best attracts such scholars. We, in industry, must do our part by not stealing such men from the universities and thus destroying the power to educate and train new men.

Chart 6, page 19.--In this chart we show our resources in manpower to carry on research. I don't like this chart. It does not show a reality toward the facts of life. As you can see, the total of research engineers and scientists available in industry, Government, and nonprofit institutions, is not impressive for the task of survival for our country.

Chart 7, page 20.--This chart is fascinating. I took it out of the duPont house organ, where it was intended to educate duPont employees in the economic facts of life. The figures which go back 100 years are supposedly to scale. They are based on social science statistics, so please do not fall victim of their supposed accuracy or try to apply them to four decimal places. The conclusion is, I believe, a fair one.

The man of 1855 worked hard in a manual sense. He chopped his wood; carried water; harnessed the team; followed the plow; fed his stock, and so on. He was a pretty busy machine. Next to him was an old friend, the domestic animal which filled in with the heavier tasks of hauling loads on the highway, in the field, and on the treadmill. To the right of the horse is a symbol that is hard to see--it is so small. It is a New England powerplant, an early water wheel powerplant. Its contribution was small relative to other sources of energy. The clock symbol shows that people actually worked well over 12 hours a day in order to furnish the goods and services and produce the standard of living represented by the symbol of the horn of plenty on the extreme right.

Fifty years later, as you see, the steam engine had come into general use. Early automation had already begun to appear. Horses began to take a licking. Now look at what happened to the clock. Or look, more importantly, at what happened to the standard of living. The "standard of living" is merely a phrase, which means the capacity of the economy of a country to produce goods and services, divided by the population--which is a nice statistical concept. To you gentlemen it has a specialized military meaning. It means capacity to wage war. That symbol is your capacity to defend the country.

Let's turn to 1955. The man now is awakened by an electric clock turning on his favorite morning radio program, perhaps turning on the coffeepot and, to the more mechanically minded, perhaps even shutting his window. After a meal prepared in an electric mechanical kitchen, he steps into his power-driven automobile in the basement of his home

CHART 6

RESEARCH ENGINEERS AND SCIENTISTS, 1941-1955

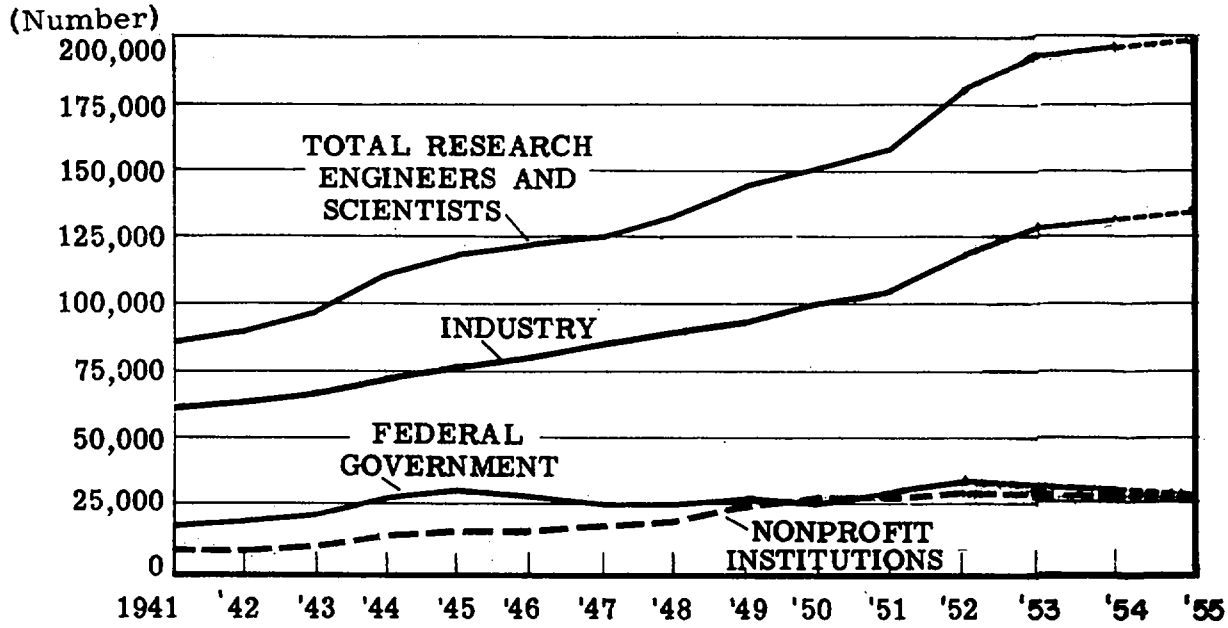
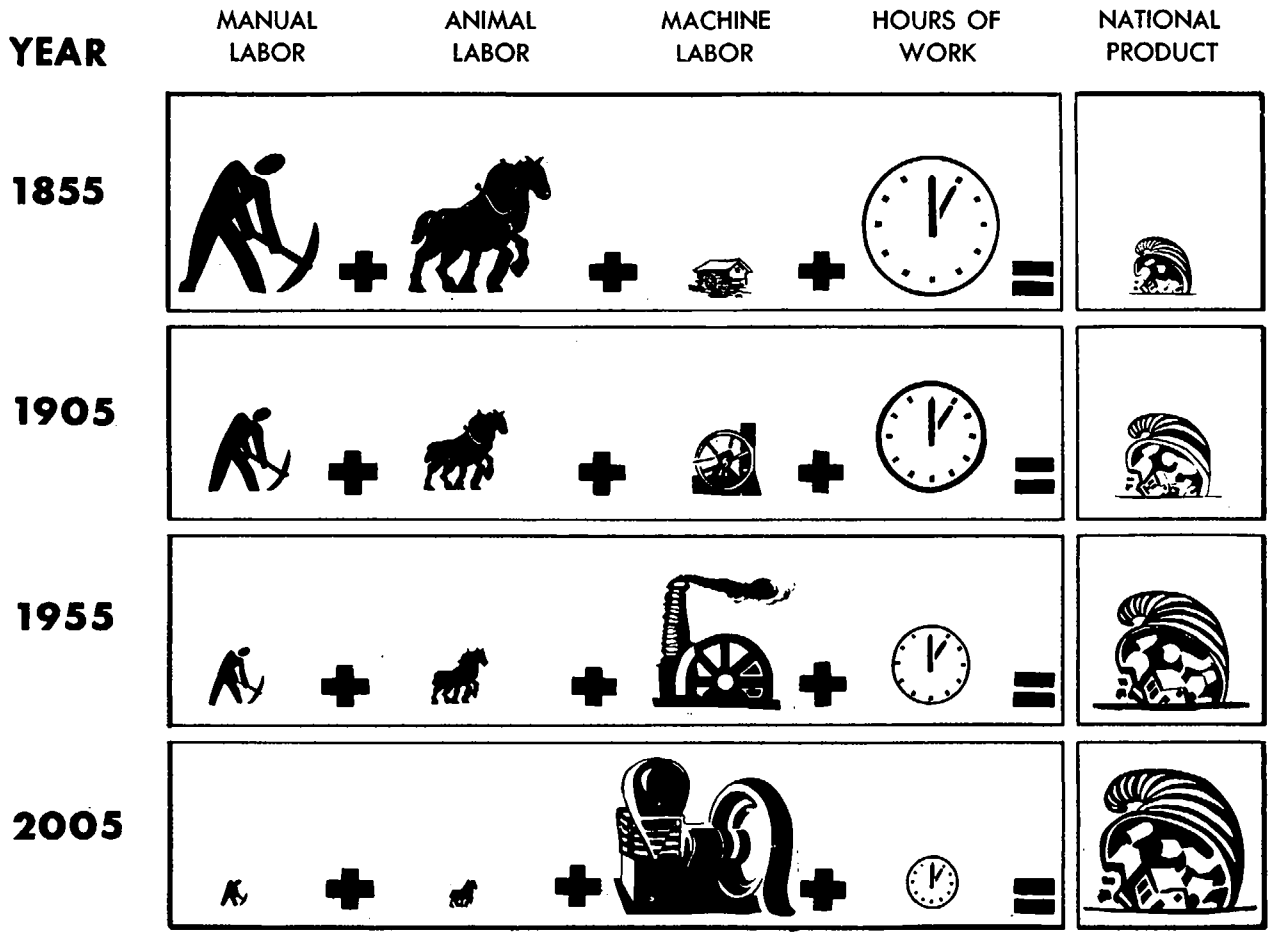


CHART 7

THE MACHINE vs. MEN AND ANIMALS



SOURCE: *E. I. duPont de Nemours & Co.*

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or garage, not walking 50 feet. He drives to the basement of his office; then gets into a power-driven elevator which hoists him up to the office, where he slumps into a chair, where his physical work is about over.

The animal in 1955 is getting to be a sort of rare beast who inhabits mostly those very beautiful areas run by "Associations for Preserving and Upgrading Horseflesh in America."

The machine, on the other hand, has now incited many of the non-scientific engineering and economic minded writers who prolifically have been complaining--not so much recently--that man has created a Frankenstein monster that will eventually gobble him up.

See what has happened to man's clock in 1955. You know that in the current labor demands they are talking a 30-hour week. You remember that the 40-hour week was a depression borne concept--not to shorten man's labor on earth but to spread work by that queer osmotic process of politics, and which has now become a fine symbol of man's emergence from a captive of duty to the promotion of leisure.

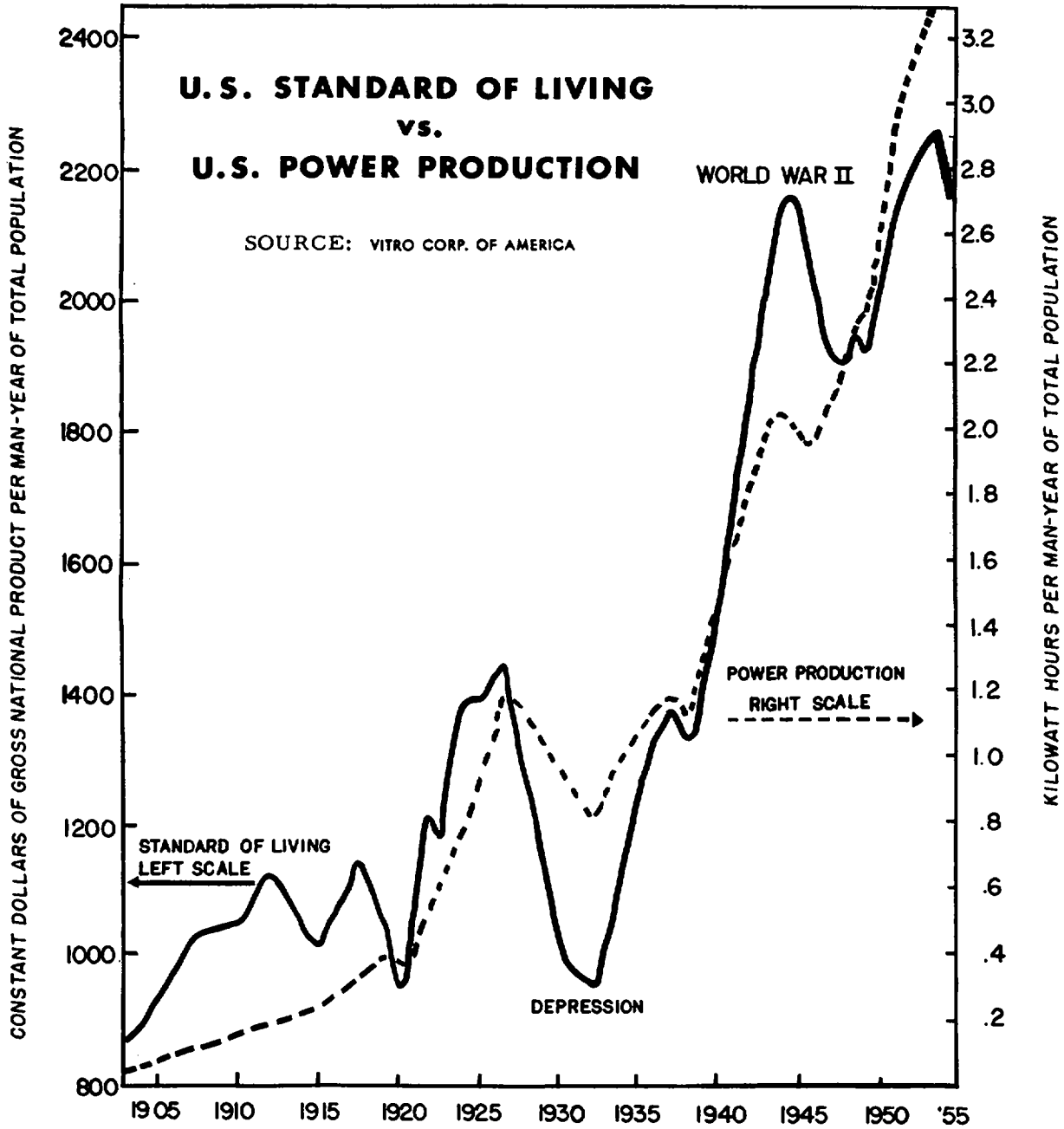
And today, where is the standard of living? It is tremendous in terms of any recorded economic history or for any form of civilization in the world.

And now the chartmaker drew on his fancy for the year 2005. Our man now is awakened by his radio clock; his breakfast is all ready to be served; he merely has to roll over to the edge of the bed and let gravity sort of deposit him on his feet. I am sure he has a motor-driven zipper on his pants. The result is, his "duty" clock shows only 30 hours a week.

Let us now take a look at the future standard of living. In some ways it is a little horrible. It is like the little child getting lost in a candy store after hours. I am not sure but what we one day will have economic indigestion from sheer luxuries. The symbolism is, I hope, quite obvious!

Chart 8, page 22.--This chart is an original one. It was designed to eliminate, as far as possible statistical gimmicks, arbitrary terms and industries, and basic assumptions. It begins at 1902, the first year of which the utility industry compiled nationwide statistics.

CHART 8


U.S. STANDARD OF LIVING
vs.
U.S. POWER PRODUCTION
SOURCE: VITRO CORP. OF AMERICA
WORLD WAR II
POWER PRODUCTION
RIGHT SCALE
STANDARD OF LIVING
LEFT SCALE
DEPRESSION
CONSTANT DOLLARS OF GROSS NATIONAL PRODUCT PER MAN-YEAR OF TOTAL POPULATION
KILOWATT HOURS PER MAN-YEAR OF TOTAL POPULATION
2400
2200
2000
1800
1600
1400
1200
1000
800
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
'55

In order to eliminate the effect of a growing population, our curve represents the kilowatt-hours of energy available for the production of goods and services per unit of population in the United States. On the same chart is overlaid the best available figure for the standard of living in the United States. Government statistics we used and reduced to a so-called standard dollar to avoid the exceeding inflation of our currency. Here, again, the figure represents the value of goods and services produced per unit of population.

I am sure you will be struck by the fact that these two curves follow the same course for over 50 years. Since the demands for power have doubled approximately every ten years during this period, this means that today's power available per unit of population is approximately thirty times as great, and in spite of this fact the standard of living has risen in a parallel manner as will be seen from the chart.

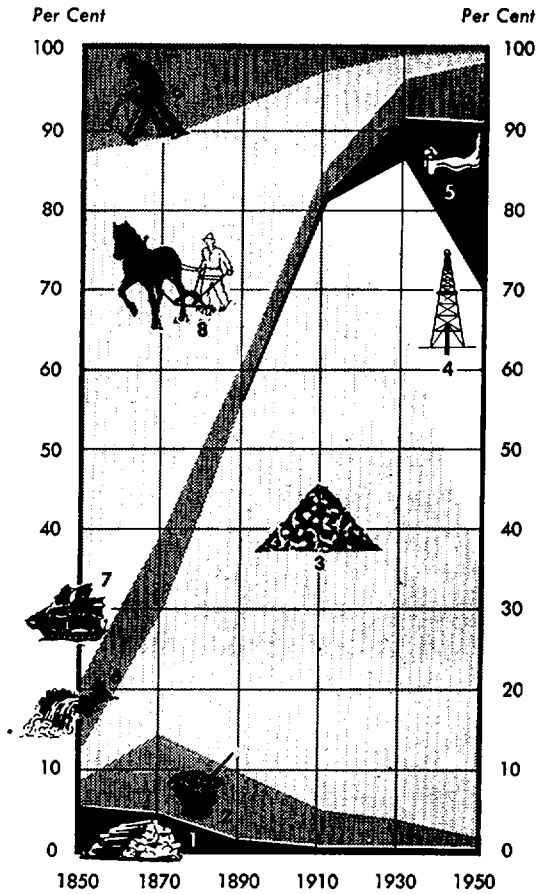
Of course, there are errors in such a simplification. In the first place, the gathering of the statistics introduces errors, particularly with respect to the economy. Secondly, the standard dollar introduces errors and, lastly, there are omissions which must be quite obvious. These lie in the field of the energy available, which are not included in the Edison Electric Institute power statistics.

I think we should conclude with the thought that our capacity for national defense which is measured by the strength of our economy and our ability to produce is a direct function of the power and energy sources that are available.

Chart 9, page 24.--What are the sources of energy that the utilities require to produce these results? Chart 9 is a fantastically interesting diagram. I hope it is reasonably accurate. On this chart the energy derived from burning wood fuel disappears as a factor as of today. Yet you can well remember the use of wood fuel in the Civil War to run the locomotives, the river steamboats and portable power and thermal devices. It must be remembered that this is a chart of percentages and merely shows the interplay of fuel energy sources throughout the 100-year period.

Next you see the contribution made by the fuel, anthracite coal. To all intents and purposes, this is, likewise, becoming an insignificant factor, even though in tons the figure is still a substantial one.

CHART 9



1953 Annual Report of the Twentieth Century Fund

Next we come to bituminous coal, an area largely ruled in recent years by the policy of John L. Lewis and his union. While this is still a major source of fuel energy, it is almost matched, currently, by the contribution of oil and, in turn, by natural gas. There is no doubt that its percentage of the market will be unlikely to regain its former stature and that oil and gas is providing nearly double the available energy.

At the top of the chart will be seen the contribution of waterpower, draft and work animals, and manual human labor. In spite of the politically developed waterpower resources, basic studies indicate that in the long run this will continue to supply not much more than a twentieth of our power needs. Taken in the context of the available fuel supplies for the future, it should be quite clear that civilization will, before too many generations, have to find new power sources, since the fossil fuels represent the stored-up sunlight of an ancient geological period nearly 300,000 years ago, and once burned, are not replaced as a natural resource. This, of course, brings in implications of peaceful atomic power and the role that it will have to play.

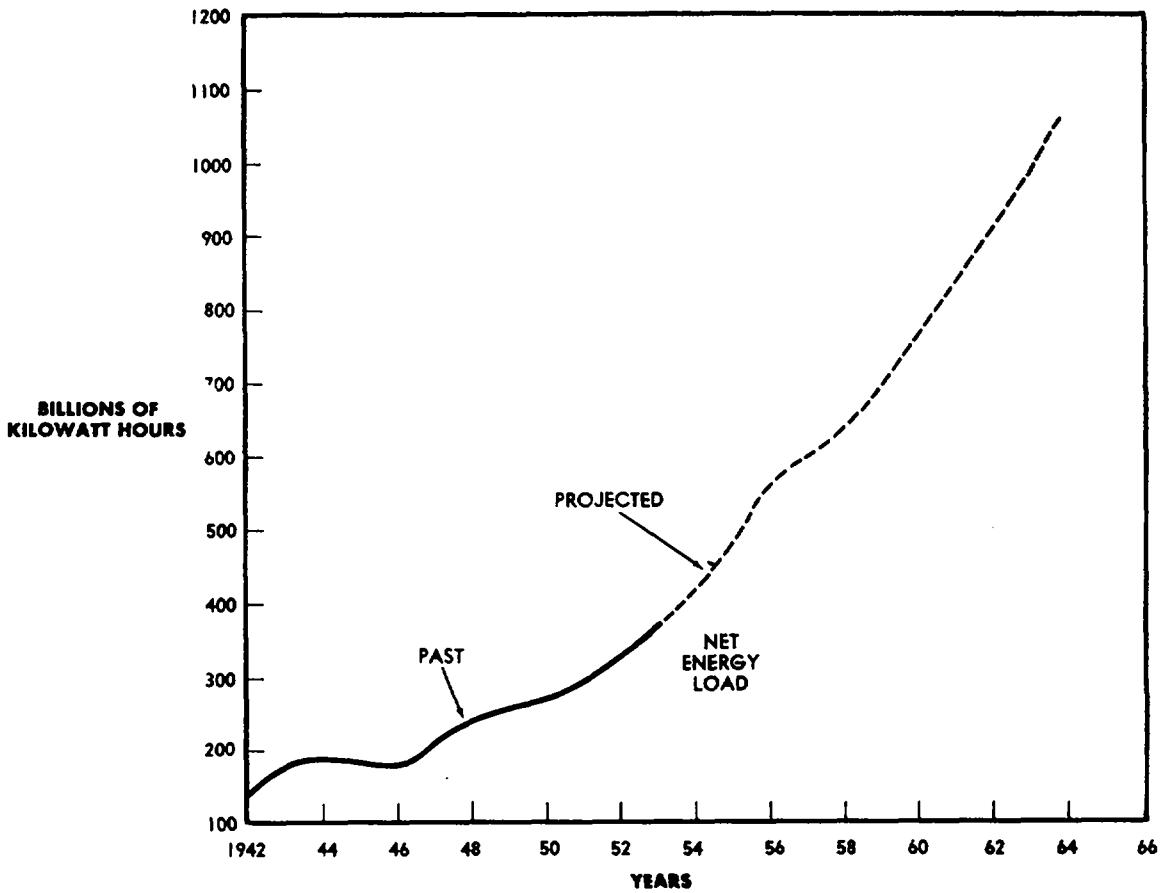
Chart 10, page 26.--This chart is a projection of the utility industry. The first solid part of it is the amount of energy it has been compelled to furnish to the economy. Beyond it lies the projection of need. It is a very interesting fact that every ten years the generation of energy by such utilities doubles. As we have seen, this has gone on for 50 years, which means that we have something like 30 times the energy today that was generated 50 years ago. If that be true, in ten years it is going to be 60 times that energy, and in ten more years it is going to be 120 times as much. This cannot go on indefinitely, however.

Such figures stretch the imagination. For instance, we now have only 30 billion dollars' worth of powerplants in existence and there will be a like amount needed in the ten years ahead. Similarly, this would mean 60 billion of today's dollars for the next ten-year increment if there is no change in this "law." Nevertheless, the utilities of the United States have laid down this type of program for the immediate ten years ahead and have committed for nearly half of this amount.

Chart 11, page 27.--This chart shows where the energy must come from. At the left is the computed requirements for up to the year 2050. This chart was compiled by Dr. A. C. Monteith of the Westinghouse Electric Corporation which has played a key part in atomic power development. Remembering that the United States consumes, roughly, 25

CHART 10

POWER GENERATION OF CLASS I UTILITIES



Sources: Past—Edison Electric Institute
Projected—Electrical World

CHART 11

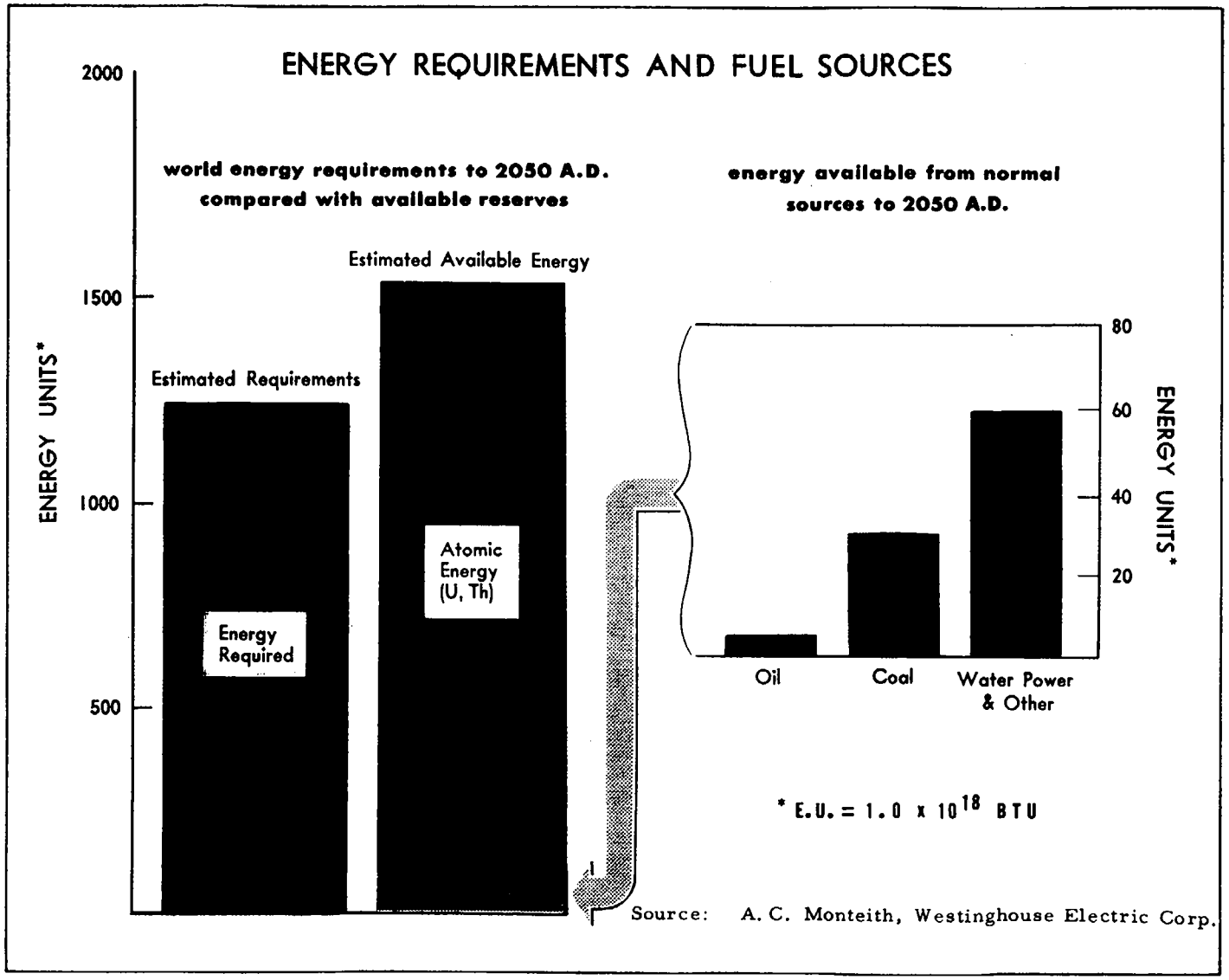


Chart: Vitro Corporation of America

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percent of the energy generated in the world, with only 1/16 of the world's population, it is obvious that should the point 4 program of the United States Government ever become a world policy and the standard of living of the more backward economic nations be brought to our standards, the implications are, indeed, staggering.

At the right of the chart is the calculated total of available energy known to exist in the earth's crust and being developed by waterpower. It includes the sum total of the fossil fuels and the assumption that all of the uranium and thorium in the earth's crust will be available for atomic energy. It is clear from this chart that the sum total of the fossil fuels, if burned to extinction, plus the developed waterpower added thereto, is a relatively insignificant part of the total need by world civilization, and that the case for atomic power becomes one more of economic necessity than of economic competition. It should be clear that waterpower looms more important than on the previous fuel energy chart, due to the fact that rain falls every year and, as long as the sun furnishes the energy for the lifting of the water, it will go on indefinitely. Hence, over a period of time, waterpower will catch up with fossil fuels, which are steadily being exhausted and are not being replaced.

Thus, if you ask: What about the debate as to whether atomic energy will compete with coal? One can say: that is a debate for the people who do not see much beyond their noses, because before long there will cease to be a choice; and necessity will show that you jolly well will have to use a new source of energy. But even so, the best sources of information revealed by the Atomic Energy Commission today would indicate that if all the uranium and all the thorium produced were made into fuel it would barely carry you beyond 2050 or at the most, a few years later.

This week there will be at Phoenix, Arizona, I believe, for the first time, a very novel scientific gathering for a symposium on solar energy. It is amazing to know that the sunlight which falls on the roof of your house is hundreds of times the amount of electric power you use to run your electric equipment. The amount of power from the sun which falls on an acre of ground in a temperate climate is more than the power of a Diesel locomotive. But at present you can't use it.

Unfortunately, the solar energy does not arrive in a form which modern engineering can readily harness. This is not to say that a basic

scientific engineering approach to this problem will not be successful. Plants photosynthetically store up the solar energy but their efficiency ratio is only on the order of 1 percent. Scientific breeding has produced plant mechanisms that can operate at 2 percent. While this is encouraging, it is not yet a solution. Of course, that is only an example of one attack on this problem.

And so we are right back to our original problem again. Where will such ideas come from? Must we go back to Europe, or can we in the United States solve problems such as this fundamental challenge to science? If we are going to be world leaders, we have to solve this matter. We have to be a little less materialistic.

In the early days we found rich forests and virgin lands that supplied more than our needs. Now we are reaching what the economists call the law of diminishing returns, and to reverse the trend we must harness new ideas from new research.

Perhaps you are familiar with experimental houses that have been constructed here in the United States which are heated solely by solar radiation. This approach is obviously in its infancy and cannot even be compared with the present status of energy from atomic sources. Atomic energy in turn, while rapidly advancing technically today, cannot compete with the economics of electric power from traditional fuels which have been developed since their inception over the past 75 years and now represent one of the most advanced engineering and scientific developments of our time.

Thus people who look at a new atomic plant and say "that plant does not compete with our present steam powerplant" fail to see the significance of comparing our first atomic power engineering effort with their highly refined and developed chemical combustion steam plant engineering effort.

Perhaps a good example would be that of Commander Whittle and his first jet engine attempt. I was one of the aircraft industry executives at that time who exhibited some skepticism because of its poor fuel economy. How wrong we were! There has recently been placed one-quarter of a billion dollars worth of jet transport orders by the hardheaded leaders of the aviation industry who have no fear that they will not compete with the traditional piston engine and the other motive power types. To be sure, this took a great deal of research and development.

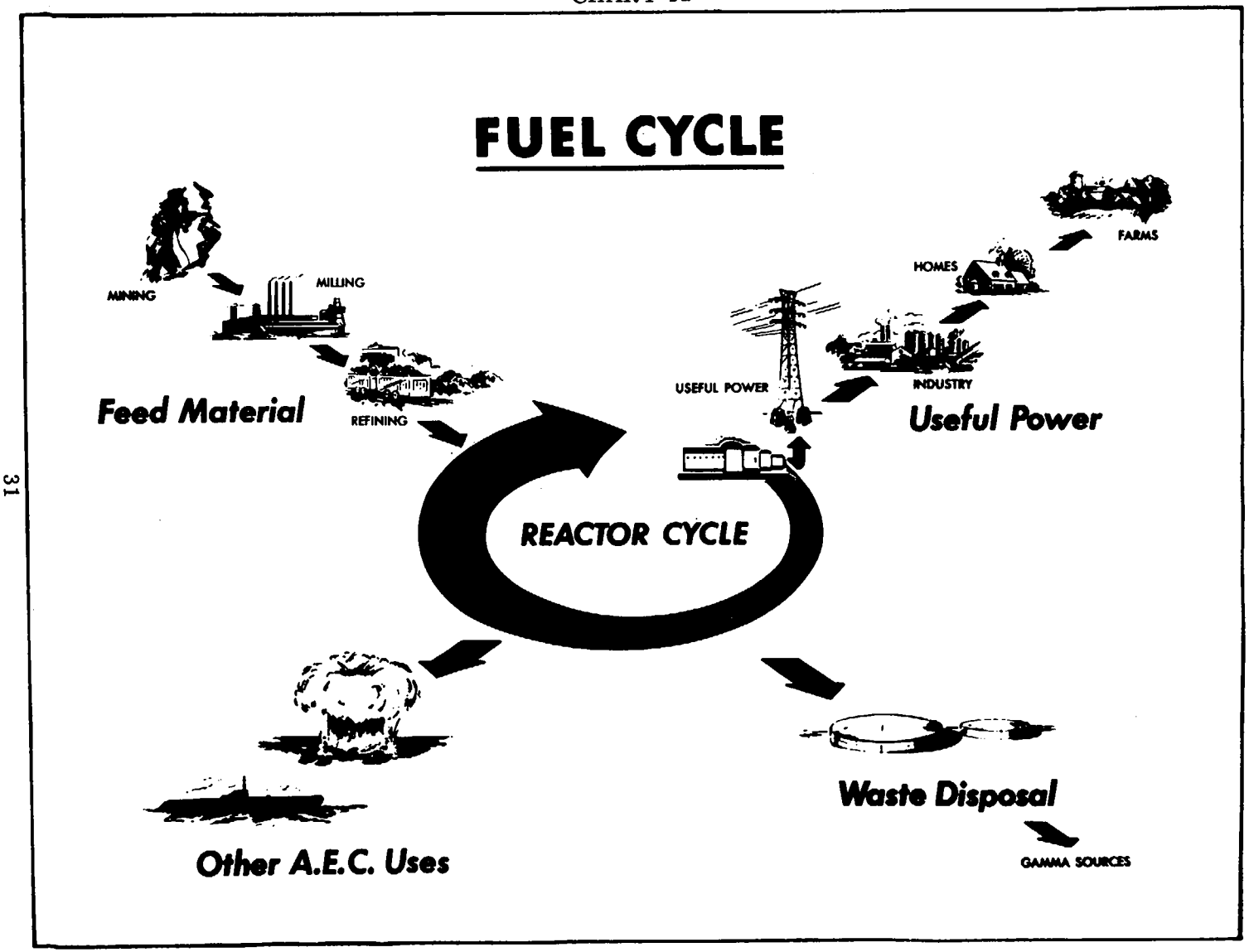
When General Hap Arnold became excited at what he saw in England, and heard of what was going on in Germany, he ordered the turbine brought over to the General Electric Company to see if they could make it here for military purposes. At that time fuel economy was 400 percent worse than for a traditional aircraft enginer. Many of us in the industry felt that there just wouldn't be enough fuel, logistically speaking, to make such a weapon effective. I, for one, failed to see what research and development could do with ample funds from military sources. And perhaps the payoff is that competitive maritime vessels are now being built propelled by gas turbine drives.

There is also the great task of pumping oil and gas 2,000 miles from Texas to the North to the refinery markets. It is done by the gas turbine-driven powerplants. There are many many more applications that are currently going on. They are competitive. I am sure you all know what the gas turbine is doing now, not alone in the military field of propulsion, but also in commercial transportation. All this has come about in that brief period between 1942 and 1955--13 years. Who wants to bet against the next 13 years on atomic power?

Chart 12, page 31.--This chart shows the cycle of atomic energy. At the top on the left one sees the mining of uranium and thorium, atomic energy resources. How many of you know that here in the United States we produce only a minor fraction of all atomic energy resources, yet it is a 100-million-dollar-a-year industry? You may think of it as a pick and shovel enterprise for a bunch of old prospectors with beards and Geiger counters, digging up little pot holes of uranium. Hardly so. In Canada alone there has been committed an anticipated 275 million dollars worth of investment in mines and refineries, largely in one area of Canada. That is some measure of the size of this branch of the atomic energy industries today.

Next we come to the ore beneficiation and the refining-to-metal stages. The first stage, after mining, of producing ore concentrates is also done by private enterprise in the United States. However, beyond this point it has been a Government monopoly to take the ore concentrates and produce uranium metal. This is a very large operation, indeed, and the present plans of the Atomic Energy Commission are to invite private industry into this field. A great deal of research and development will be required in perfecting these processes and many new approaches have been examined in various Government laboratories.

CHART 12



SOURCE: Vitro Corporation of America, 1955

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The next step, of course, is the reactor itself. Toward the upper right the chart indicates the many uses for atomic power from reactors.

At the lower right are indicated the gamma sources of radioisotopes. The Quartermaster Corps has a vital interest in these sources in its approach to the storage of foods and the preparation of foods to feed the armies. The oil industry is also looking toward radiation sources as the possible basis of refining oil by radiation so as to do away with those enormous thermal plants requiring very high pressure.

It was in the NEPA project that I mentioned earlier where we had occasion to wonder what a lubricating oil would do in a reactor under radiation. We hired the Standard Oil Development Company of California and directed them to make studies. Gentlemen, it was fantastic--seeing lubricating oil turned into wax or rubber-like substances under radiation. Don't mistake me; I don't mean paraffin wax. I don't mean buna or butyl rubber. These are broad terms. What I do say is that the effect of radiation on such matter was to unlink many of the chemical linkages that are the base of compounds and, under radiation energy, to relink them. For instance, monomers, large complex molecules, can be hooked into polymers, and the result is waxes and resin-like substances from oils.

So the farsighted oil companies now are building research laboratories to see how far they will be able to go. As an example, ethylene, the basic petroleum substance, when subjected to radiation of the proper energy content, can be converted directly to polyethylene. Polyethylene is the product, you know, which is going into the cosmetics field for plastic bottles, for packaging, and for many uses, industrial, personal--too many even to describe.

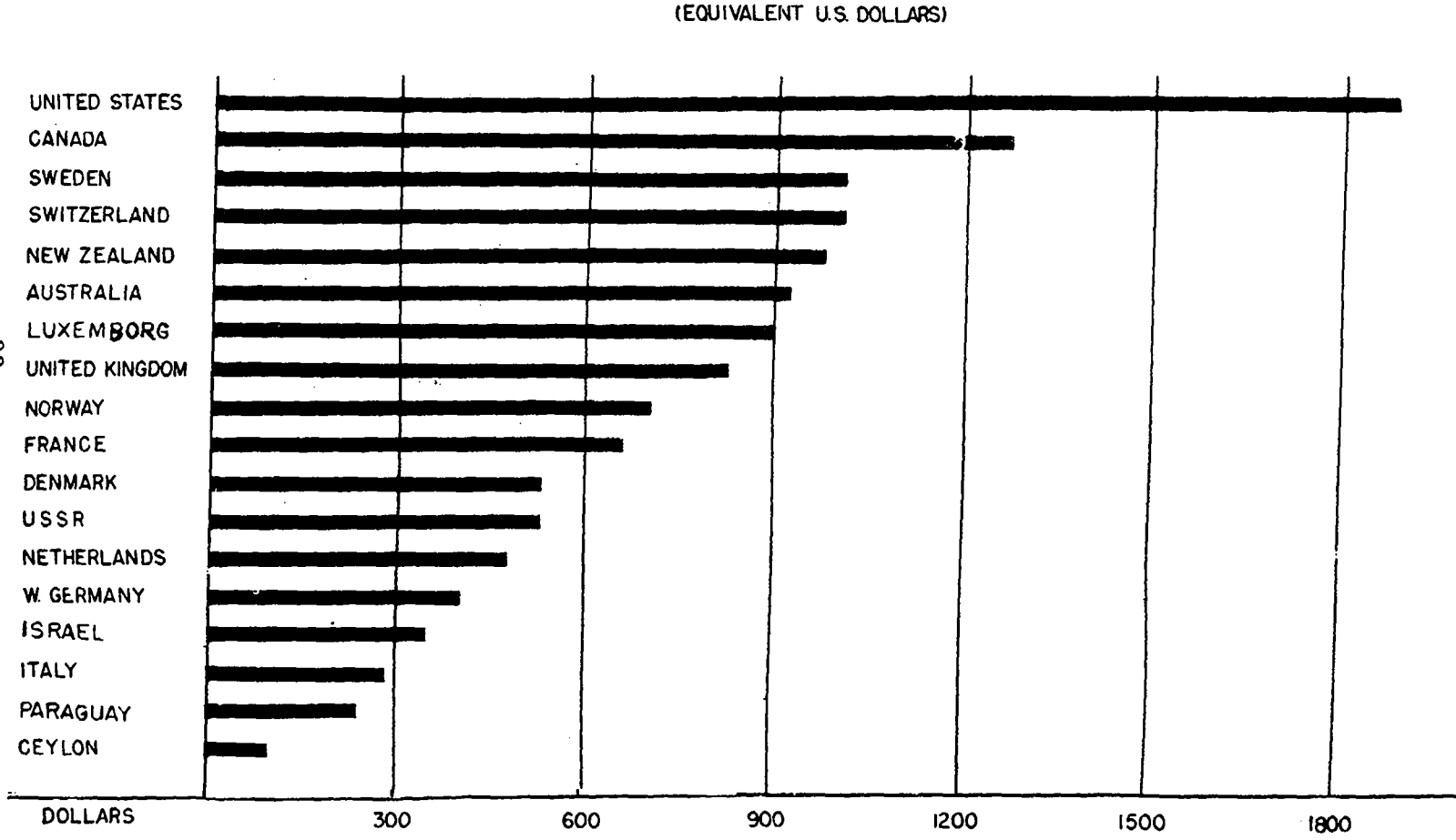
At the lower left are shown the weapons using atomic energy. The chart is of course highly oversimplified. But notice how this rough schematic chart deals with the possibilities as they concern your capability for waging war, or the country's capability of building up its economy by new energy sources, new tools.

Chart 13, page 33.--This chart indicates the standard of living of the principal countries of the world from the latest data available. Notice the U.S.S.R. Russia has been working her way up this ladder, and she is well on the way up. Notice who is at the top, and who is next. Our domestic political and economic practices flow over our unlimited

CHART 13

PER CAPITA INCOME

1953



border into Canada, and thus she comes more nearly to reflect the American system than any other country in the world. Our system, however, does not flow over the Mexican border. There are reasons for this, very powerful reasons, many of which are in the area of psychology and social affairs.

I do not mean in this talk today to discount any of the fields of knowledge that pertain to human beings as human beings. We are talking about the possibilities extended to human beings if they have the will to accept the challenge of science. I am not saying whether they will do it or whether they won't. This chart will show a very strange political fact, one that can be regarded as a political phenomenon.

The countries with the highest economic standards in general have the most parliamentary forms of democratic government as we understand them. It is quite reasonable to suppose that this fact has not escaped the planners in the Kremlin and to it may be ascribed the vast attention given by them to the training of scientific and technological experts, and to the growth of their basic industries. It is their rapid progress in these directions which should give us pause to reflect and to be concerned.

Chart 14, page 35.--In this chart is shown this country's comparison with Russia in gross national product, hence its national defense potential. Compare the United States, Western Europe, and Canada, with their 624 billion dollars of gross national product, against the Soviet bloc with only 214 billion dollars. I am not one of those people who are worried about whether we can defend ourselves against Russia. This chart is a comforting thought to me, because I believe through you and your professional associates we can utilize our great resources as intelligently as any who may wear the professional soldier's uniform anywhere. In fact I know you can do it better. So, with your capabilities and this measure of potential support, I feel we can preserve our Nation. Our problem is to utilize our knowledge to maintain the lead which we now have.

Chart 15, page 36.--Here is what should concern us. This chart shows the production of engineering graduates in the United States and in Russia.

Since we are a democracy, it would be my wish that every citizen, as well as you gentlemen in the military services, read some of the new

CHART 14

GROSS NATIONAL PRODUCT
1954

(EQUIVALENT U. S. 1950 DOLLARS)

	POPULATION (MILLION)	GNP (BILLION)	GNP PER CAPITA (DOLLARS)
UNITED STATES	162	307	1900
WESTERN EUROPE	335	292	872
CANADA	15.2	25	1650
TOTAL WEST	512.2	624	1218
USSR	214	120	560
EUROPEAN SATELLITES	94	47	500
ASIAN SATELLITES	618	47	76
TOTAL SOVIET BLOC	926	214	231

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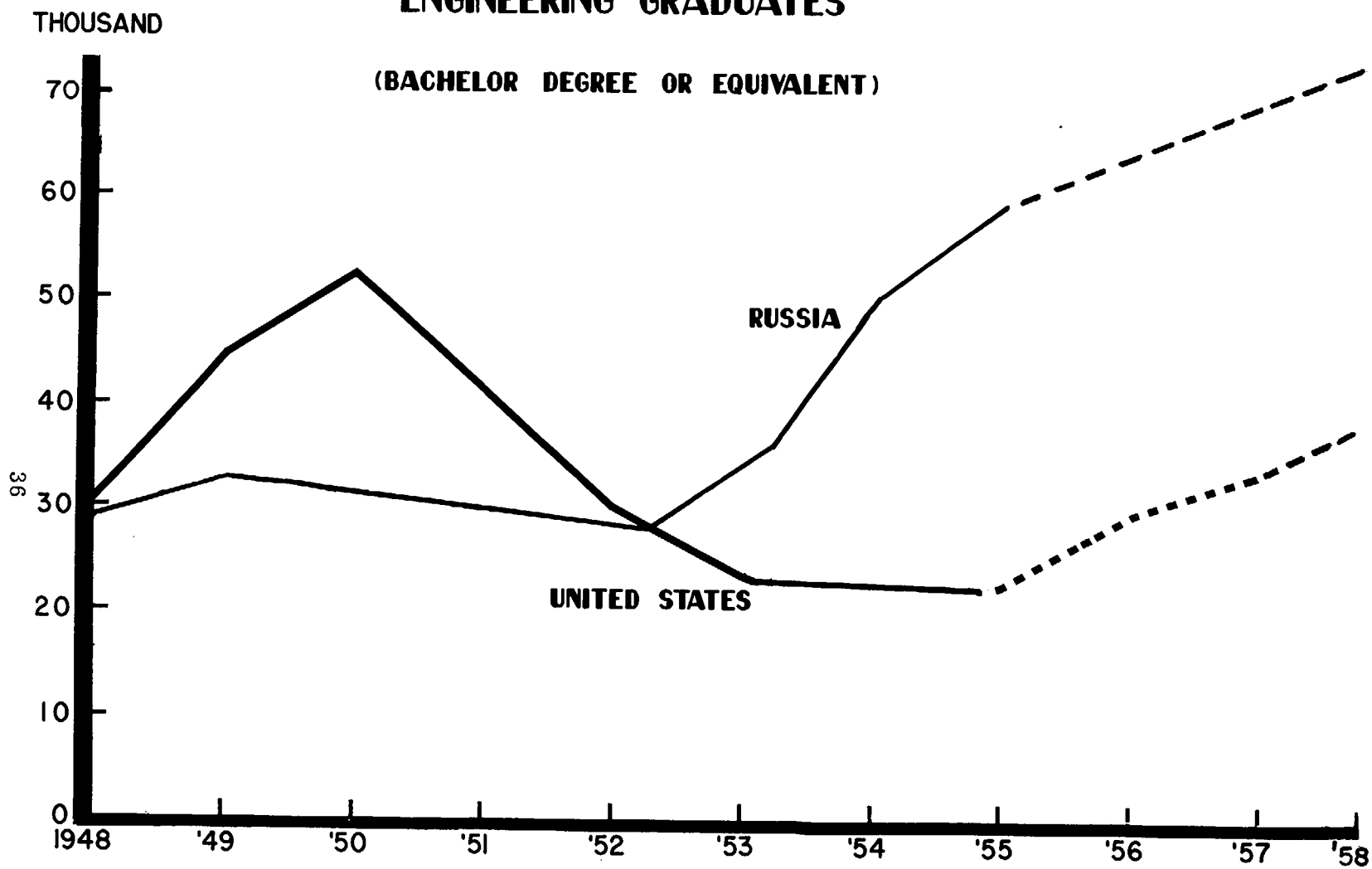
CHART 15

ENGINEERING GRADUATES



1954 ESTIMATED TOTAL SOVIET ENGINEERS 541,000
ESTIMATED TOTAL AMERICAN ENGINEERS 650,000

authoritative analyses that are now being published by leading scientists and educators and scientific bodies on the nature of this problem. We have touched on it before in these remarks and I now only wish to add that, from all of the authorities with whom I have discussed the matter, it seems clear that the Russian scientific and engineer-trained graduates are entirely up to what we call American standards.

The Russian engineering curriculum is just as stiff as any in this country. Don't think of it in terms of men who are middle-aged engineers in Russia today. These young men are really being trained.

I am told by Dr. John R. Dunning, the Dean of Engineering at Columbia, with whom I have been associated for a number of years and who served on the advisory panel of the Joint Committee on Atomic Energy of the Congress, that, in his study of the Russian effort, he finds that they are doing as good a job as we are. Furthermore, he advises that there are over 4,000 research institutions in Russia. These are new developments, gentlemen. They will bear watching.

The Russians have another technical level of education. Thus, there are 300,000 graduates on the technician level who have the equivalent of two years of engineering. We have very few of them in the United States. Therefore, the curves on this chart do not present the whole story.

Chart 16, page 38.--This chart shows the electrical power available in these two same potential enemy groups. You will note we have 950 billion kilowatt-hours to their 224 billion. But do remember that the Soviet type of political machine can put a higher percentage of this power to work for defense and force its population to consume less.

Chart 17, page 39.--This chart, gentlemen, shows a challenge. We have in previous lectures discussed coal hydrogenation. Many of you know that the Germans, cut off from petroleum resources, made good, even high-grade, lubricating oil by hydrogenating coal. We are pretty good at lifting such processes from Europe. We have lifted a great many of their original techniques, as we did for the synthetic plastics. Most of it was done, of course, on agreements, with financial backing involved. But we are often inclined too much to take the credit for these things.

CHART 16

ELECTRIC POWER PRODUCTION
1954

	(BILLIONS KWH)
UNITED STATES	545
WESTERN EUROPE	336
CANADA	69
TOTAL WEST	950
USSR	146
EUROPEAN SATELLITES	67
ASIAN SATELLITES	11
TOTAL SOVIET BLOC	224

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CHART 17

TECHNOLOGICAL DEVELOPMENTS HAVING FUTURE POTENTIAL

ATOMIC POWER

COAL HYDROGENATION

OIL SHALE EXTRACTION

RADIATION SYNTHESIS

ULTRASONICS

- - AND OTHERS

Coal hydrogenation, of course, is economically not of great importance in America. It is entirely conceivable in the long range that we will not be able to afford to burn coal; it is too valuable as a source of raw material.

The same thing might be said of both petroleum and natural gas. All of these fossil fuels are basic sources of carbon compounds which, in turn, are essential to our form of civilization in a material sense rather than as a source of energy by combustion.

We have already explained the relationship of radiation synthesis as a challenge to petroleum refining and for possible polymerization techniques. Many astute scientists feel that this development in a broad sense can lead to a large variety of new applications. Similarly, ultrasonics is the application of the physical phenomena for useful purposes. Because we do not hear such "sounds" their use has only recently come into wide application. Such vibration rates have the property of killing bacteria, shattering structures, inciting and promoting chemical reactions, and is a very important tool in the non-description testing of materials. This is another striking example of the application of new knowledge.

Chart 18, page 41.--This chart represents certain cases selected at random showing new materials derived from basic research and technological developments. It is to be remembered that the work on synthetic rubber was done in Germany and exchanged under license with some of our leading oil companies. As a political aside, it might be pointed out that the oil companies were at one time in severe disfavor for having done so. And if I recall correctly, they were slated to have been prosecuted as having acted against the public interest. Neoprene might be said to be a special rubber-like material with new properties developed by an American organization.

Generally speaking, the plastics were first pioneered in Germany and from there spread to American industry which has, in turn, moved forward rapidly in this field.

Next come the fibers in which a great deal of fine work has been done in Europe and in the United States. Many other plastic families

CHART 18

NEW MATERIALS DERIVED FROM

RESEARCH AND TECHNOLOGICAL DEVELOPMENT

- - - - - - - - - -

BUTYL & BUNA RUBBER - NEOPRENE - PLASTICS

NYLON - ORLON - DACRON - RAYON - ACRYLON

UREAS - NITRATES - FORMALDEHYDES

ELEMENTAL METALS - RARE EARTHS

ANTIBIOTICS - PHARMACEUTICALS

SILICONES - FIBER GLASS

CELLULOSE PRODUCTS

- - AND OTHERS

have sprung up, the ureas, nitrates, formaldehydes, and so on. One of the new and promising fields of metallurgy lies in the area of little known elemental metals and that strange group of elements called the rare earths. Examples of the first group are: titanium, zirconium, hafnium, germanium, etc., and of the latter group, the cerium compounds and their associated rare earth elements.

The field of antibiotics and synthetic pharmaceuticals was pioneered, again, by the Germans and has become a very large industry in the United States. We have done especially well in the field of antibiotics.

It is said that a new branch of chemicals, analagous to the silicons, will give us new materials with interesting properties. Silicon has many of the characteristics of carbon and may be said to lie between carbon and germanium in its interesting properties.

Fiberglas is again a new and interesting field and very useful to the aeronautics industry as a structural material. Lastly, cellulose products and cellulose chemistry as an example of chemurgy, or the science of adapting farm products for other than food, is a challenging area.

In reviewing the list above, it should be clear that many of them are byproducts of the atomic age and the new atomic knowledge and are excellent examples of the role of fundamental research, applied research and of development.

In the metals group, the horizons have expanded so rapidly that many scientists refer to the age that lies ahead as the coming "Age of Metallurgy."

I believe that, in closing with these examples, we have followed fairly well the scope for the lecture which was assigned to us today. As you must have perceived by now, the purpose of the lecture is to serve as an introduction to the science and technology section of your curriculum and has merely been designed to stretch your imagination and to exercise it to prepare it for the tasks that lie ahead.

I hope that, if possible, we can now see the many new horizons and the fundamental aspects of the problems in science and technology

which bear a close relationship to your task, to our survival as a nation, and which, in certain cases, point toward needed improvements in the American economy which is the fundamental basis for our defense posture and, hence, the preservation of our way of life.

QUESTION: Mr. Ward, I was very much interested in your diagram in shadow which predicted the completion of the supply of atomic energy in about 100 years. I understand that at the Geneva Atomic Energy Conference in August a paper was presented which indicated that, if we can learn to harness thermonuclear power, there is sufficient hydrogen in the ocean to supply all the power resources of the world for an indefinite period. I wonder if you want to comment on that at all.

MR. WARD: I don't really want to, but I will. It is true. Let's look at the periodic chart of the elements here on the stage. It will be noted that the heavy elements, including the transuranic elements, go up to approximately element number 100. However, the elements beyond uranium, number 92, may be considered not to be present in the earth's crust.

All elements can be broken down into a nucleus and a series of electron shells or orbits separated in proportion to their particle size by enormous distances and normally in violent motion. These elemental particles are either positive or negative electrically or are neutral. Gravitational and electrical forces hold them together, much as the gravitational forces hold the solar system in its present relationship. It is a fact of nature that the degree of instability in the heavy elements is such that they tend to break down under the proper circumstances into lighter elements predominately close to the center of the periodic chart, in the neighborhood of silver. In breaking down the process of fission, large stores of energy are yielded coming from the nuclei of the atoms which lose mass in the process. Turning to the light elements, beginning at hydrogen, a reverse phenomenon can be said to occur. As an example, hydrogen can be built up into helium by the process believed to exist in the sun. In doing so, even higher yields of energy are obtained as will be seen by turning to the principles of atomic physics.

Since, as your question indicates, there is a limit to the supply of fissionable elements and since there is a vast supply of hydrogen in proportion thereto, the implications of your question are correct. Again,

for reasons of atomic physics, the heavy hydrogen, or hydrogen of double weight found as an isotope, and known as deuterium, is most useful for this purpose and there are vast quantities of it in the waters of the ocean. However, as within the sun and other stars, such light elements are joined together by enormous gravitational forces and the agitation of violent thermal energies. These conditions are not normally to be found on earth.

This has been accomplished in the hydrogen bomb by using the fleeting pressure and release of high temperatures in the first microseconds after the detonation of the atomic bomb to trigger the thermonuclear effect. From this point on the entire release of energy is so violent that it cannot be contained or controlled. To control this is the problem before research.

Dr. Homi Bhabha startled the world at the Geneva Conference by predicting that the control of the thermonuclear process would be solved and hence we could get a regulated release of energy from the reaction. He indicated that in his opinion this should happen in the matter of only several decades. This, in turn, brought out the fact that the United States is now engaged in such research. But authoritative statements of a guarded nature made by our authorities state that this has not been solved in a practical manner as of today and it is a task of vast difficulty.

To get our perspective in order, hydrogen as you see it on the periodic chart has an atomic weight of 1.008, whereas helium has a weight of 4.003. If you could compress in a thermonuclear sense four atoms of hydrogen you would have an atomic weight of 4.032 and if it resulted in a formation of an atom of helium there would be a loss in mass of .029 mass units. Substituting this in the equation, $E=mC^2$ with pounds for mass units, you can readily compute that you would have the most enormous release of energy presently available to science and much more potent than the equivalent release of energy in the fission reaction of uranium or plutonium.

Thus, Dr. Bhabha was right and the only trick in his statement lies in the fact that no one, yet, is known who can solve how to control this violent reaction occurring in microseconds at temperatures of millions of degrees centigrade, and still remain around to observe the results.

QUESTION: Mr. Ward, you scared us a little bit in saying that we are going to run out of the conventional sources of energy. I would just

like to see if I understood it correctly. As I saw the chart, within 100 years our present conventional sources will supply us only about ten percent of our energy. Now, in all of the other predictions I have heard--I won't call it optimism--but the largest consumption has shown something in the order of at least 200 years or more of available energy from coal. A quick calculation shows that the doubling of energy every ten years in your prediction will exhaust the fossil sources much sooner than is commonly expected. You may be right, of course, sir. I wonder if you would try to unscare us a little bit.

MR. WARD: A fair question. We are discussing a statistical exhibit with all the limitations that we have imposed on statisticians and their art. The chart was made by an authority, Dr. A. C. Monteith, who is head of the Nuclear Energy Department of Westinghouse Electric, an authority in this field. What are his assumptions? What were the assumptions of the gentleman whom you quoted as to the fact that coal will last so much longer? You recall how exponentially the demand for energy is going to rise not only in the United States alone but throughout the world. People say that the cause of war is the unequal resources of different nations and the envy that they excite. Similarly, our point 4 was to help bring foreign standards more nearly up to ours.

Just think of the amount of coal that must be burned if the rest of the world comes up to the American level of prosperity! If they and we are to double every ten years--and you are entitled to your own prediction in that regard--I suspect that Dr. Monteith may have rationalized his case by producing the statistics that I have shown in our chart.

On the other hand, someone interested in the coal industry, and not interested in nuclear power and not agreeing with some of us that coal is going to be more valuable as a source of chemical compounds than for fuel, can make different assumptions and arrive at a very different conclusion. And now, we are back, in a manner of speaking, to the fact that, if we try to be economists and lay our predictions end to end, we would reach no conclusion. Do not forget that fossil fuels, and certainly coal, get more and more difficult to extract and this is the nature of the problem in Great Britain.

I am informed that Great Britain has large untapped coal resources but the seams are very thin and hence expensive to mine and the supply of miners is becoming more limited. So that what do we find? England has today embarked upon a program for making all of her future power

developments so that they will be atomic fueled. And so today she has a two billion dollar nuclear program laid out without regard to any coal-fired plants.

As you know, they operate through an Electricity Board which in their country is a governmental monopoly. There is no interplay of competitive forces. I was fortunate in meeting and talking with Lord Walter Citrine, the head of British Utilities, and he said that their coal seams were getting to be unminable and that their people don't wish to work in the mines. Thus you see two factors at work: (1) economics; and (2) the free choice of free people to work where and how they wish.

A few weeks ago I was in one of the most modern of Pennsylvania coal mines. I discovered there several mines with wide seams and mines with narrow seams. They must be worked differently. To emphasize the human factor I learned that miners who work in the narrow seams and have to squat all day will not work in the mines with thick seams where they can stand up. They like to squat!

What is the point? The point is that in England you can't even squat any more. The seams are too thin and are getting worse, I am told. It is not that they do not wish to mechanize, because they claim that even mechanization does not solve their problem economically. Likewise, the English sons of English miners seem to be turning away from the mines as an occupation for, perhaps, more pleasurable tasks. However, the Polish and Italian miners who are surplus in their countries and would like to come to England are forbidden to do so by the political power of the British unions.

Now, having examined so many of the factors that are involved, it is only fair to say that someone must place an estimate upon the amount of coal in the crust of the earth and the portion of it that can be economically mined, and then bring in the question at some future date as to when it will be too valuable to use as a fuel. This gives us plenty of room for Dr. Monteith's view, the view that you cited in your question, and also for your own interpretation.

I am very pleased that the question points to a possible fallacy in one of our exhibits. This shows the critical attitude and I will now leave with you the question of whether Dr. Monteith is right or wrong and whether England is wrong in laying down two billion dollars from its economy, more restricted than our own, to base all of their future

needs on atomic generated power rather than on an extension of their coal-burning power-producing industry.

QUESTION: Mr. Ward, you indicated that in addition to the technological developments that hold prospects for the future you had some others you might tell us about. Would you?

MR. WARD: It is always difficult to answer a question such as this because of the limited time available. Perhaps I can draw from a project in which my own company is deeply interested. Back in 1938, at Columbia University, two Ph. D.'s were curious about what happens in an electric arc discharge as the current is increased beyond the limits of modern technology.

Other investigations had, from time to time, given some thought to this problem but rapidly given up their interest when they found that there was no way of preventing the arc electrodes from being consumed. Thus most all arcs for metallurgical or other purposes operate below 3700 degrees centigrade.

Mr. Preston Bassett, an official of the Sperry Corporation and a former associate and founder of that great company, did some work in this field, among many others, only to be disinterested when its limitations became apparent.

It is now found, however, that this so-called impractical area of operation furnishes a new environment available for research at very high temperatures beyond where materials can exist except in such form that they may exist upon the surface of the sun. Under these conditions, atoms are highly ionized and in a vapor state of great agitation.

This led the two scientists I mentioned into an area where they patented some of their new discoveries, which we are now earnestly reducing to practical possibilities. We have in mind presently that their process may solve one of the great shortages in our American economy where we have had to import from foreign sources, over long water routes, a necessary mineral required by our metallurgical industries. In the event of all-out war, that shortage could work against us very much as the importation of bauxite for aluminum production did in World War II. Hence, we believe that there is a strong national interest in such a solution.

There is already a committee in Congress concerned with this problem and they have tried many solutions. Many other experimenters are at work on competitive processes following much more traditional lines. As would be expected, we do have some native ores of the material but they have proven to be low grade and expensive to extract. Since materials are not in a "chemical state" in the environment, we have indicated that this new process presents a novel solution or attack on the problem. Naturally, many other questions have been raised and it is our firm belief that there will be an extension in our chemistries into the physical-chemical realms of very high temperatures for which there are, today, no existing data.

The recent symposium on solar energy held at Phoenix, Arizona, devoted a great measure of its attention to temperature ranges much above those now available and which could be used for continuous processing.

These are new challenges for science. A recent edition of the "Scientific American" devoted to itself to heat and, in particular, the realm of higher temperatures than those now available. I realize this is only a single example in answer to your question but, as you see, the mere mention by title would be quite unconvincing.

QUESTION: Mr. Ward, with respect to basic research, what can we do to encourage this atmosphere which you indicated the European countries have in greater measure than we do?

MR. WARD: That is a wonderful question. Some day you should get some better equipped scientist than myself to tell you the answer. But here is my analysis.

If you are an industrialist, for instance, you are bound to be called upon for many speeches and to take part in various civic activities. You become an important character--depending, of course, upon the size and prominence of your firm. To many people such an individual becomes an authority not merely in his own field but on other subjects, from running our Government, through that of the Department of Defense, to bringing up children or, in fact, solving many of the complex questions involved in our economy.

But on the other hand, if you are merely a professor, let us say, in higher mathematics, no matter what your stature may be, it is unlikely

that you will be called upon by local Chambers of Commerce to make their annual addresses. It might also be said that the salaries would not at all be commensurate one with the other.

Again on the other hand, men who are destined to devote their lives toward the extension of knowledge, without a direct motivation as to how they will apply it to make money, are only likely to be stimulated where there is, in return, a kudos which serves to compensate them. This is a fundamental of human nature and, unfortunately, we do not generally furnish such a favorable atmosphere or climate here in our country, where our measure of success tends to be materialistic.

I might take as an example an incident which was reported somewhat fully in "The New York Times." As many of you know "The New York Times" is one of the few newspapers that pretends to do a job in the field of science reporting. The Times had followed the career of Dr. Einstein from the time he landed here in New York. It had presented in its columns the problem to which he was dedicating the latter years of his life--the development of a set of equations which would explain the behavior of all matter and energy throughout the universe.

After a number of attempts he produced his final equations, I believe in 1953, but alas, no one was able to solve them, including Dr. Einstein himself.

Now let us turn to Hungary where the Russians, after taking over the government, found that the Hungarians failed to be impressed by the character of their political leaders put in by the Kremlin. In an effort to build up the prestige of the Hungarian parliament, the Kremlin looked for a man of prominence in the nation and picked on the professor of higher mathematics at the great University of Prague. Here, already you can see that any similarity with American customs has broken down.

This distinguished man, after a brief service in the parliament, convinced himself that he was being used, and that he was not having any effect on the captive government that was either to his or his nation's credit. In the usual manner he managed to escape from his native land and, finding that he must earn a living elsewhere, he came to our shores where he obtained a job as professor of advanced mathematics at Indiana University, at what the Times reported to be a very modest salary. I feel quite certain that there were very few Americans who realized that such a distinguished man had come to our shore.

It turns out that after the Einstein equations were published in scientific periodicals, one day, the professor at Indiana developed their solution. Since Dr. Einstein himself had failed, this was a sensation in ivory tower circles. The Times picked up this item and went out to interview the professor. I recall quite clearly that the article quoted the correspondent as saying: "Professor, you must be a genius." To which with true humility, the professor responded: "Oh, no. Dr. Einstein is a genius, I am a mathematician."

As most of you know, this is not an academic question and the moral is fairly clear. Perhaps we should first try to see what are the issues involved. Dr. Einstein, in bringing out his first or Special Theory of Relativity in 1905, met with no favor among the physicists and scientists in general and it was not until he predicted an event which had never been observed, and which was subsequently observed and found to be true, that his theory received wide acclaim. I am told this took 16 years and that the event was a prediction that at the next total eclipse the stars in the daytime would be found to be positioned not where the star maps calculated them to be, if they were near the sun at the time of the eclipse. He calculated the exact displacement. Photographic observations in Brazil confirmed his calculations which were based on the fact that a light ray, through $E=mC^2$, is also mass and as such would be affected by the gravitational pull of the sun and would cause the rays to bend as they came around the rim of the sun. An astronomer looking up the ray would, therefore, see the star from the beam of light at a position in the direction which he was looking, not realizing that the light had come to him on a curve around the sun. This accounted for the displacement and the calculation was based on the gravitational pull of the "mass" of the ray of light from the star. However, these equations failed to take into account such things as the gravitational field and this was dealt with in the 1916 Einstein Theory of General Relativity. However, the electromagnetic fields did not yield to these equations and Dr. Einstein felt that until his basic equations could include these phenomena also, it could be said they did not represent the fundamental behavior of our physical environment. It was these latter equations which he derived and could not solve.

What civilization in the future will ascribe to the value of this quantitative knowledge of the universe is difficult to forecast. But, I believe, it is fair to say that in the long history of mankind it will stand out far beyond the number of cakes of soap produced by the mythical industrialist whom we cited as becoming a typical hero in our present-day economy.

Your question deals with how we will produce these men. My answer is that it is unlikely that we will produce such people until you and I and the rest of us Americans cease calling such people "eggheads," "longhairs," and the like, and view them with the same respect and give them the same encouragement that we render today to the practical man of affairs.

COLONEL WALKER: I wish we could continue our discussion, Mr. Ward. It has indeed been a great pleasure to have you with us again and to enjoy another of your outstanding presentations. On behalf of all of us here this morning, I sincerely thank you.

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