THE CONTRIBUTION OF THE ELECTRIC POWER INDUSTRY TO NATIONAL DEFENSE

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6 March 1952

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Washington, D. C.

Dr. Philip Sporn, President of the American Gas and Electric Company and its subsidiaries. He is a scientist, engineer, and administrator, who has devoted his entire life to the advancement of the electric power industry, and is noted for pioneering work in this field. He is responsible for the design, construction, and operation of the Twin Branch Power Station which operates at a boiler pressure of 2,300 pounds per square inch, the highest pressure regularly used in an operating station in the United States. He had many responsibilities in developing the techniques of operating all the power systems of the eastern United States as one unit during World War II. This vast network was governed by the Philo station of the Ohio Power Company, which was designed and constructed under Dr. Sporn's direction. He is the moving spirit in development of the "heat pump," which may completely revolutionize all present concepts of residence and commercial heating. He has been the directing head of many experiments now being conducted in the art of electric transmission. He has written many papers for technical and scientific societies and has received many citations for his contributions to the industry. Most of his professional life has been spent with the American Gas and Electric Company and its subsidiaries, where he has risen from an engineer through all grades to his present position of President.

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MR. SWAREN: Gentlemen, all of you are familiar with the old saying "If you want a job done well, turn to the busiest man you can find and there you will get your job done." We have done just that this morning, but we have also gone a little further. As all of you are aware, in any industry there are always a few men who really represent the industry. Some of them have represented it so long, even from comparative youth, that we call them "elder statesmen." This morning it is my great pleasure and honor to introduce the elder statesman of the power industry, Mr. Philip Sporn.

MR. SPORN: Major Swaren and gentlemen: I think you gentlemen should know--the major knows it himself--that the major is very favorably prejudiced toward me and that the prejudice is one of long standing. So when he says something nice about me, I greatly appreciate it, of course, but you ought to know that it is mixed with that favorable prejudice.

I want you to know that I am very happy to be here and I hope that, when I have finished my discussion, you will feel the time you have spent here will have been to some purpose. I want, not to apologize, but merely to preface my comments to you with this: When I accepted the invitation to talk to you this morning, I had in mind preparing the paper that I would present to you and that it would be carefully prepared. I ran into difficulties, having to do primarily with very important problems of national defense, and although I was able to put together the material that would form the substance of a paper, I actually didn't have the time to sit down with a secretary and dictate a text that I could easily present to you. So what you have before you are a series of charts and tables, all bearing on the question of the contribution of the electric power industry to national defense. I will talk about these charts and tables extemporaneously, but still--I hope--connectedly.

Figure 1, page 21.--One of the main items that I want to touch on with you is the place of power in defense and in defense mobilization. This, like all the exhibits, is, I think, almost self-explanatory, but perhaps some further comment could sharpen it. The first thing I want you to observe is that the two curves, utility electric power production--going back to 1929--and gross national product, go hand in hand. You could almost substitute one curve for the other. From this one must conclude that when national product goes up, utility power production goes up; the corollary of that is equally true: Gross national product cannot increase without a corresponding increase in utility electric power production.

The point of interest in this connection is that in a country as industrialized as the United States, no mobilization is possible without power mobilization; and, no defense production--that is even more important--is possible without power production and power mobilization. All the magnificent plants which have been created in the past and which are part of the great peacetime and defense capital of this country become useless, are inert, and produce nothing either for the civilian economy or for the defense program if the power to move them isn't available. This means the right kind of power, at the proper place, of the right quality, and everything else that goes with it.

Again from this relationship there follows another important corollary that should, perhaps, be self-evident. Many of you have by now learned the lesson--I know Major Swaren knows it as intimately as anyone on the face of the earth--that if you destroy the sources of power, you destroy the ability to produce defense or war material, and that if what you are anxious to do is to destroy that productive capability, you can perhaps do it as economically as possible by concentrating on the destruction of the power facilities. That, I think, took World War II experience to teach us. We did not, I am fearful, know that lesson until after the war, but when we got to the records in the postwar period, we saw how badly we overlooked it. I hope that if we ever have to fight another war, we will not again overlook that lesson.

Table 1, page 22.--The next point in connection with power in defense mobilization is shown, I think, clearly on table 1, which really shows what kind of job we have done in the development of power resources in the United States. In this table we have listed most of the principal countries in the world and have given for each the population as of 1950, the electric energy produced in terms of kilowatt-hours, and, in the last column, the kilowatt-hours produced per capita. I have underlined in that table the countries with populations of 40 million or more, the principal countries of the world from the standpoint of strength, certainly economic and military strength. This is a very interesting table, because among those countries you will find China with its 465 million people, having power production per capita per year of 4 kwh and Pakistan with a population of 75 million, having an annual power production of 2 kwh per capita. You will find no other major country in the world approaching our kilowatt-hour production per capita as of 1950; I think we are still moving ahead of the rest of the world.

For the Union of Soviet Socialist Republics we have the figure in 1950 of 466--just about one-fifth of ours. That obviously is a very important source of strength to our country. I don't have to dwell on this point because I am sure that it is clear to all of you.

Table 2, page 23.--To indicate in another way what kind of job we have done in mobilizing and developing the power resources of the country, and how industrial power requirements are being met, I have prepared this

table showing industrial electric energy consumption for the three decades 1920 to 1950, the portion of this power purchased from utilities, and the portion generated by industry. It is important here to note the remarkable change that has taken place in the quarter century 1925 to 1950.

Note, for example, that in that interval the purchases of energy by industry have increased from some 29.9 billion kwh to 193 billion kwh, a 6.5-fold increase. The industrial generation, that is, the part generated by industry itself, only increased from 23 billion kwh to 58 billion kwh, a 2.5-fold increase. You will also note from the last column that the percentage of industrial energy consumption generated by industry itself went down from 44 percent in 1950 and it is still going down very rapidly.

From these facts this conclusion is warranted: Industrial power is utility power. Utilities are now supplying 80 percent of industrial power and with each year they will supply a greater percentage. In order to have power for industry, the electric utilities must be able to provide that power. If they have the power, industry will also have it.

Table 3, page 24.--There is another very interesting point, indicated in this table, in connection with the industrial power supply. Here we have shown for the period 1937-1951 the total production of energy in the United States by private enterprise power and the part produced by government power operations, whether local, state, or federally owned.

You will notice in 1937, as recently as 15 years ago, only 7 percent of utility power was generated by public power groups. In 1951, the figure was 18.5 percent. It is also important to observe that this figure is not following any definite trend; that is, it doesn't have an irrevocable trend. For example, in 1949 the percentage was almost 20, yet it was down to 18.5 last year. There is a good likelihood that this percentage may continue to go down. Certainly it will if the private industry does the job which, in my judgment, it needs to do, and which I think it will do. From that table it is also safe to make this generalization: Utility power is fundamentally, in the ratio of over 4 to 1, private utility power. So much for the significance of electric power in industry and in defense.

I would like to show you a series of data in the form of tables, indicating the history of public utility power, its growth and development, and whether, as a contribution toward defense, the utility industry has kept up with the requirements of the country for peace and defense.

Table 4, page 25.--In this table we have indicated the growth of power use in the United States from 1935 through 1951. Over that period of 17 years, you will notice that there has been an enormous growth in

the use of power. As recently as 1941 all plants contributing to the public supply--that includes public and private--generated only slightly less than 165 billion kwh. During the active period of the war there was an enormous increase in power use. But the greatest increase has taken place in the postwar period. Since 1946 there has been an average increase in energy use of over 65 percent; in the case of some utilities, the increase has been more than 100 percent.

There is no question, therefore, that there has been an amazing growth in power supply and power use. Of course, as all of you gentlemen know, when we talk about production of power, we are also talking about use. Power is the one commodity in our economic system that you can be sure is not being put away on shelves.

Table 5, page 26.--Let us examine this table which indicates again the kind of job that has been done in power and the contributions that have been made through power to the defense program, in both World War II and the present period. Here we have shown annual "noncoincident peak loads." These are the same figures that you saw before. We have given in the third column the "installed capacity of public utilities," and the difference between the two sets of figures we call "indicated reserves." Actual reserves are always something in excess of the indicated reserves. In the last column we have shown indicated reserves as a percentage of the noncoincident peak demand.

You will recall that in 1939 we really started our earnest defense efforts preceding World War II. But at the end of 1939, when we were already acquiring considerable momentum in the defense effort, we still had reserve capacity of 35 percent of peak load, amounting to 10 million kilowatts of generating capacity to take care of any additional production capacity that could be activated or built. As we got further into defense and then into war, that reserve capacity figure dropped. By 1944 when we really reached our peak in war materials production--there was some tapering off in 1945--that reserve had dropped to 21 percent and it was still a good reserve. Thus, during this period we were fighting the war, building the munitions and the sinews of war by utilizing existing plant and by living off reserves that had been acquired, built in previous years. Some new capacity was added, as you can see, but the amount of new capacity was considerably less than the additional load that was being served.

That is the thing that should be done in a well-administered economy, one that takes prudent care to see that both civilian and even defense requirements are in a position to be met. It is what I have called on another occasion when I have had the privilege of talking before this group, taking advantage of the WR^2 function, or the flywheel effect. The function of the flywheel is to carry the power supply system over the period when power input is less than the demand or power output. The flywheel furnishes some of the momentum for that purpose. It is a basic and fundamental concept and the reserves are really the flywheel effect in a power

supply system. The economy must live off the reserves during emergencies. Then, after the reserves are reduced, and the economy returns to an ordinary cycle, which may extend over a decade or more, they unquestionably should be restored.

You will notice how beautifully that worked out in the period following World War II. In 1945 we ended the year with 27 percent reserves. In 1946, contrary to the expectations of every economist of any consequence, instead of a retarded industrial production, we had a resurgence of industrial production and generating reserves went down to 11.8 percent. In 1947, while capacity was being added--slowly, because it takes time (you will notice that generating capacity increased from 50,317,000 kw in 1946 to 52,322,000 kw in 1947)--the reserves dropped to 5.6 percent, and dropped even more in the following year, to 5.2 percent. Then in 1949 we began once more to build up our reserves, returning to a relatively normal figure.

In 1950 we ran into Korea, with our second major defense effort in a decade, and again we increased capacity, as you will notice, some 5 million kw. But we also met an increase in peak demand on the country's power system of 9 million kw and it barely was supplied by the reserves. By the end of 1950, reserve capacity dropped to 6.8 percent. Last year the reserves amounted to 7.8 percent, and I am fearful that this year they may be somewhat lower.

Many of the essential factors haven't been determined, but steps are under way, as you will see very shortly, to bring the reserves back to the right figures for a defense mobilization period. They may not be the right figures for a normal period, but eventually they will get back to that. I think this table is a splendid illustration of how well basic philosophy can work, provided it is properly set up, with competent people having the right sense of responsibility.

Those of you who follow this question must know that essentially there has been no such thing as a power shortage in the United States. There have been dire predictions; they have not materialized. There is hardly an industrial country on the face of the globe that is not facing major curtailments of industrial production. It is true of England; it is true of France; it is true of most of the other countries. In order to see the kind of job being done historically, please examine the following table.

Table 6, page 27.--Here we have concentrated on the economic phase of power mobilization and the development of power resources. Shown here are annual capital expenditures for electric utility construction in thousands of dollars. For example, the first figure in the front left-hand corner is some over 36 million dollars and the others are correlative, during the period 1936 to 1951, with the estimated figures for 1952.

You will note that for a period of about some 10 years, 1936-1946, the private, municipal, and state--that does not include Federal--utility systems spent on an average about a half billion dollars for electric facilities. But note what has been happening since 1947. In 1947 expenditures were some over 1.37 billion dollars; in 1948, approximately 2.08 billion; they have been running above 2 billion every year since then and the estimated expenditure this year will be in excess of 3 billion dollars.

In 1946 when it first began to be evident that something had miscarried in the calculations of the economists about the depression and the industrial recession that was going to follow VJ-day, and that the country wouldn't have a recession but was going to have a boom, I made a very quick economic survey. I made a survey of what was being done in the way of expansion of utility facilities by 10 major power groups in the country, communicating with the heads of these companies myself. I came to the startling conclusion that they were collectively engaged in an expansion of power facilities that would involve expenditures of between 6 and 6.5 billion dollars for the industry in the period 1946-1951. I circulated a confidential memorandum to this effect among the heads of these companies. Some took it in stride; but as to others--if I had predicted that their systems would be bombed, go up in smoke, or that some other dire calamity would hit them, they wouldn't have been more aghast at what the survey revealed was going on. They were fearful it was going to ruin them individually and the industry collectively. There would be no way to raise the capital. Six billion dollars is a lot of capital when you have to worry about paying for it. They thought that planning to make that much expenditure indicated some kind of improvident action on their part.

But they didn't stay shocked--they recovered. It is interesting that we now find the history of 1947 to 1951 showing that these utilities actually spent almost 11 billion dollars in that five-year period. In 1952 alone they will spend over 3 billion dollars. And because of the fact that this expansion was planned and the plans were developed, the capital was raised, the facilities created, we have today the power system that we have, and we have the power facilities, not only for the peacetime requirements of the country but for the normal and expanded defense requirements--and these requirements are enormous.

Now, I want to get into the economic phase, since you gentlemen, I think, cannot afford to overlook the economic phase of what is going on. If there is any sense--and there is a great deal of sense of urgency--in this defense program in which we are engaged, it is to protect the social-economic system that constitutes this country: our great inheritance of resources which has been expanded by industry into our standard of living; our system of government; our system of freedom; our system of enterprise wherein people are free to develop themselves, their talents, and their abilities.

On the other hand, I don't think there is a thinking man in this country who isn't persuaded that, if in that mobilization process we end up by adopting principles and ideas which are no better than those coming out of the kind of social economic system against which we are planning to defend ourselves, we will suffer what may be the greatest defeat in the history of this country.

This economic system, this magnificent system of ours, is in danger and it deserves to be defended. I would like to show you what is happening in the power industry, by way of example, and its effect on our national economy.

Table 7, page 28.--I have shown in this table a "composite income statement of privately owned electric light and power companies in the United States," in the six-year period 1946-1951. These are, of course, privately owned companies; 81.5 percent of the public utilities of this country are privately owned. These are interesting figures but the most interesting figures are these:

If you will look at the figures for 1951, you will find that the taxes paid--it takes taxes to run a government and it takes taxes to run a defense program--by these utilities in 1951 amounted to over 1.13 billion dollars. This was more than 56 percent of their income before taxes. In other words, the government, collectively--municipal or county, State, and Federal--actually took more out of the income left after paying merely operating expenses than everybody else, including all the owners of the property who put up the capital. Actually, you will find all capital charges in 1951 were only 86 percent of the taxes.

I am going to talk to you a little bit about taxes in the hope that many of you will be stimulated to follow that up. I want to draw your attention to another set of data in table 8.

Table 8, page 29.--In this table we have shown what happens to a dollar of revenue to the private electric power systems of the United States--how the dollar is distributed. Now again if you will look at 1951 you will find we have reached a point where the biggest single claimant of a share of the dollar of revenues is the tax collector. He asks for a greater share than anyone else, a greater share than all the people in this industry who plan, design, operate, and run it. Their salaries and wages are only 19.9 cents out of the dollar, whereas the tax collector has claimed and received 22.2 cents.

Now I would like you to remember that the people who receive the 15.9 cents as dividends and surplus, in turn are taxed again, so that the tax collector comes in for his share of the earnings portion of the revenue dollar. If you take this second taxation into account, you will find that the tax collector ends up with something very close to 26 cents--that is

my estimate--out of every dollar collected as revenue from utility service in the United States. The tax bill will be heavier in 1952. I think that is a very important thing.

In that connection I would like to refer you to the February 1952 Monthly Letter of the National City Bank of New York, which, in my judgment, is the best written, best informed economic letter prepared; and, there are many of them prepared in the United States today. In it is a very important piece of analytical work that was done on the problem of taxation. I understand that this publication is in your library. We have provided a few copies for those who want them but we couldn't get enough copies to distribute to everyone. I would like to refer you to page 18, an article entitled "Taxes and Inflation," and discuss a few things about the tax question and the inflation question.

This item refers to the work of Colin Clark, an Australian, and one of our great modern economists. Some 12 years ago he published a book that has attained the standing of a great modern classic in economics. It is called "Conditions of Economic Progress." I am sure some of you have read it. In that book, for the first time, Clark broke down and prepared information on national income and manufacturing production statistics for all the principal countries of the world and reduced these statistics to a comparable base or rate of production per man-hour. It is not until you get down to that kind of base that you can really find the effect on the fundamental economic progress and standing of any country, and more particularly, of an industrial country.

Some six years ago, Clark presented a theory which said that "the level of budgetary expenditure acts by a more or less automatic procedure is the final determinant of the value of money, the cause taking perhaps two or three years to work out its effect."

Then he tried to determine what percentage of total national income can be taxed before you reach a period when the entire economy becomes endangered; there is general agreement that there comes a time when taxation becomes dangerous. Clark's conclusion was that 25 percent of total national income is about the limit for taxation in a nontotalitarian community in times of peace. The National City Bank Letter, in that item on "Taxes and Inflation," shows what has been happening to our own national income and where we stand in taxation in the fiscal year 1953, which, as you know, is the year that is starting 1 July 1952. The Letter shows we are reaching a percentage of over 28 percent.

I would like to point out to you again that in table 8 I showed you that in the power industry 22 percent of its income from its product goes directly to the tax collector, and if you add the collections from the individual owners, that proportion goes up to 26 percent.

I think it is very important to remember that we have had all sorts of prophets of disaster in the country. We have had our Cassandras.

Most of them have been wrong because this is a great country and it has resources in the form of its people and natural resources such as no other country has; but, the fact that prophets of possible trouble have been wrong doesn't mean certain trends that are going on cannot assert themselves to the irreparable damage of this country. There are schools of belief that we are about at the limit of what we can attempt to do with taxation and that we can carry through without ruining ourselves for a peacetime operation. What we would be able to do in case of war is another matter.

But after all, war, if and when it comes, must not find us so depleted or so spent that we are really not in position to fight a war. That may be a bad enough thing in itself. The tax question does have something to do with electric power, the job that is being done, who is doing it, and whether it is merely a question of advantage to the utilities or to a particular utility as to what kind of job is being done, or whether it is important to the defense of this country. Certainly as citizens you want to be certain that trends are not permitted to establish themselves to the point where they are irreversible and to the point they can do irreparable harm to this country of ours.

I want to talk about another item, the contribution of utilities to the current defense program, and show what the utilities are attempting to accomplish in the three-year period 1952-1954. You will recall that when we started this build-up, the defense program was supposed to be completed by 1953. We recognized that this schedule was a little more ambitious than we could undertake without getting into serious trouble, so we stretched out this period to 1954.

Table 9, page 30.--What about this period? This table shows you the capacity that has been undertaken to be installed by all utilities in the three-year period 1952-1954--over 30 million kw--and the expenditures that will have to be made. The figures for expenditures include some estimates made by my own company, but the total expenditures will be of the order of 9.5 billion dollars to carry on this work during the three-year period alone.

I want you to remember that this is an enormous program by any standard. For example, consider Great Britain, including Scotland and Wales, one of the great industrial nations of the world, and the country that brought about the industrial revolution. Great Britain has a total generating capacity of approximately 15 million kw, with a population of 55 million. In the United States we are planning to create in three years 30 million kw capacity, and to spend in the process almost 10 billion dollars. I think all of this new construction will be completed substantially on schedule. It will be a staggering accomplishment even if it isn't all completed for another year.

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Going back to the idea of generating reserves and WR^2 function that I mentioned to you earlier, I think it would be interesting to examine table 10 to see where this construction program will lead us at the end of 1954.

Table 10, page 31.--The last four columns of this table show estimates of peak loads, generating capability, and reserve margins expressed in both kilowatts and percentage of peak load. You will notice that we now estimate a reserve margin of 8.6 percent for 1952. In my judgment, the margin won't be quite that big, but that is the best estimate available. By 1953 the reserve margin is expected to increase to 10.8 percent, and by 1954 to somewhere between 9.5 and 10.5 percent.

Even for a defense period that level of reserves is not quite good enough, but the growth in reserves is being accomplished just as fast as the resources of this country--the technical facilities that this country possesses--can produce power equipment, turbines, pumps, boilers, tubes, and all the other elements that go into a kilowatt of generating capacity. No other country in the world can touch us, but even our magnificent system of industrial production cannot produce at the present time any more than that. I don't think there is any doubt that if we can keep this expansion program on schedule we will be in grand shape, whether in peacetime or in a continuing defense economy, or even if we should have to fight a defensive war.

I thought you would also be interested, before we finish this really brief discussion, if I reviewed with you some of the major achievements of the electric power industry over the last 50 years. I would like you to remember that this is a personal appraisal. There is no way you can get complete agreement among people on a subject like this. I haven't attempted to poll anybody. Nevertheless, in the light of everything I have been able to acquire about power in the years I have been working in it, I believe that a critical examination of the contribution of all engineering developments throughout the world in the past century, to the welfare and progress of the people who instituted our western civilization--and numerous and brilliant contributions have been made--will probably rate one of these developments as the outstanding one that has contributed most to the welfare and to the progress of western civilization. That engineering accomplishment would be the development of the production and use of steel. I think that has been the greatest single engineering advance of a century.

But, granting that steel needs to be given that position, it is my judgment that you would also find the development of the production and use of electric power approaches the steel development; most of that has been taking place almost entirely within the past half century. The electric power accomplishment comes very close to being the first, but definitely is the second greatest engineering contribution to the development of our world in the last century.

Now in the power field about which I have been talking to you, I believe four major achievements stand out.

The outstanding development, I think, is the Central Station Steam Power Plant. You have a model of one of them here in this building and I am sure you have all seen it. But there are power plants that go well beyond that today. The modern high pressure, high temperature, pulverized coal fired plant, with a single boiler and single turbine per unit of 200,000 kw, using 2,000 pounds per square inch steam pressure, with temperatures of between 1050 and 1100 degrees Fahrenheit in the initial stage, and with 1050F reheat, two examples of which are now being built on the American Gas and Electric System, is today's highest development of this concept. It has centralized control, attaining a thermal efficiency of 38 percent or better, and has an availability for service of very close to 98 percent. Each such unit is capable of turning out something between 1.75 and 2 billion kwh per year. It is certainly one of the great engineering developments, certainly the greatest single development in the power field which I regard so highly for its contribution to human welfare in the last century.

Figure 2, page 32.--In this figure there are some very interesting things about the trend in fuel consumption. I have given a brief sketch of that development. What we see here is the fuel efficiency--the weighted average efficiency of electric utilities, expressed in pounds of coal burned per kilowatt-hour generated.

Now we start at the beginning of this quarter century, 1929-1954, with an average requirement of 1.66 pounds of coal per kilowatt-hour. It is our estimate that by 1954 that requirement will be down to very close to one pound. I am sure you will remember that, in the light of what I have told you, this is not the best performance on the AG&E System, our system. In 1951 our best plant operated at a fuel rate of 0.79 pounds of coal per kilowatt-hour, and we have better plants in process of construction.

If you project this trend in fuel savings through 1954--and I have--the following striking conclusion results. The probable contribution to the public power supply will be very close to 500 million kwh, and 80 percent of this generation will by that time be steam, so that 400 billion kwh will be generated by steam electric plants. Considering the savings, expressed in tons of coal with average heating value of 13,100 Btu per pound, and on the basis of the average expected 1954 efficiency contrasted with that of 1929, you will find there will be saved in 1954 close to 130 million tons of coal. By virtue of that saving, you will require approximately 110,000 men less to produce this coal than would have been required at the 1929 level of coal utilization by steam power plants.

I want those of you who are of an economic bent to think of the effect of that on the national economy in peacetime, but more particularly

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in time of defense when we have to mobilize all our resources. We had to do that at the start of World War II and we certainly will have to do it again if we have to fight another war. Every ounce of our resources and every man and woman who can be brought into the defense plant will have to be used; on the item of coal production for electric power plants alone, 110,000 fewer men of high productive capability will have been saved. That is one of the great achievements that has been brought about by the development of the modern steam electric plant.

The second of these four things, that I have said are outstanding in the long list of achievements, is the grid system of distribution. We take for granted that distribution is made, but distribution is one of the prosaic things in electric supply to which very little publicity can be given. Literally hundreds of thousands of men have worked on the problem. The man who did the preliminary work on it--it was really dazzlingly brilliant--was Thomas Edison himself who designed and built a prototype of a good deal that we are doing in distribution today.

But since then we have done a great deal of work. The original concept that Edison had of the grid and tube system for distributing direct current a distance of two or three blocks actually didn't come into its own until the alternating current system came along and with it the modern system of distribution. It is ironic, but that is the system of power generation and distribution that Edison fought with every means at his command to outlaw by legal process. He was sure it was a bad thing for the country from every standpoint. But brilliant as he was, he had his weaknesses and this was one of them. Actually, the Edison idea is the grid idea we are using, and it is one of the great contributions to the economy and reliability of electric service today. It is one of the greatest developments.

The third development is one in high-tension transmission. Only a few years ago, the maximum transmission voltage was 44 kv. Then by a series of very brilliant achievements, it went to 140 and later to 220 kv. Then Boulder Dam was built in 1937 and with it the transmission line to Los Angeles, at 287 kv. Now we are building, as perhaps some of you know, a grid of 330 kv. That in itself has been a great development, but even more important in that development of transmission has been what would appear offhand to be almost an impossible idea, but which is simple enough, and which we call in the industry "ultrarapid reclosure."

All that means is that when the circuit is interrupted, the circuit breaker recloses before the load connected to that circuit has a chance to find out it is without power. As a result you can have two systems, no matter how big, and they can become separated, but through ultrarapid reclosure they will be reconnected almost in the process of being separated and power will not be noticeably interrupted.

Figure 3, page 33.--If you will take a look at this figure, you will note how that is done. It is a very unique accomplishment.

This is a diagram of two points on our system. One of these points represents one of our very large plants; the other is the city of Fort Wayne. They are separated by 75 miles of double circuit, high voltage line. On the bottom you see a series of recordings showing a fault occurring in the line. Such a fault may be caused by lightning striking the line. You see the fault and then the current starting to flow in the line. You can see that, for example, in the third trace; then the circuit breakers open; then you see the faulty lines clearing; and then you will see the power restored.

Now when this fault took place, the faulty lines in this case disconnected in 8 cycles and reclosed 11 cycles later. The important thing is that during this very short period of about one-sixth of a second the two generating systems operated entirely disconnected. But they had no time to drift apart. The circuit breakers automatically reclosed and both lines remained in operation with the equivalent of no interruption of transmission.

This is the result of work that was carried during the depression. We did such work on our system in 1932 and by 1934, working with some of our progressive manufacturers, we brought ultrarapid reclosure into being. It is interesting to note that when the development was presented before an international conference in Paris in 1938, some of our French friends said, "C'est incroyable!" But actually it is standard practice today all over the world, including France.

The fourth achievement is the development of integrated power systems over extensive areas, the idea of having a large area entirely interconnected, operating as a unit, with a multiplicity of generating sources from which power can be brought economically to wherever it is needed. That, too, is an American development; in this country we have developed the integrated system to a high degree.

Map of the United States, page 35.--I thought you would be interested in the small map of the United States showing principal interconnecte electric systems. What we show here looks like a jumble of lines. If we had had time we might have prepared a better exhibit, but if you will look closely at the map, starting in the upper left-hand corner, you will find that what we have there is a power pool. You will find it actually covers a considerable region. That pool operates in the States of Washington, Oregon, Idaho, and Montana as a single coordinated, integrated system. In 1951 that area had a capability of some 5.5 million kw.

Then coming down the west coast we find the Pacific-Wouthwest interconnected systems. That pool operates in California, Arizona, and a portion of Nevada. In 1951 it had a generating capability of 7.65 million kw.

Moving along from west to east, we find an area covering the eastern part of Pennsylvania, New Jersey, Baltimore, and Washington. The service here in Washington comes from that pool. That is a much larger group in capacity but not in other physical facilities--some over 8 million kw.

In the New York-New England area, the utility systems operate in parallel--Vermont, Massachusetts, Rhode Island, a portion of Connecticut, New York City, and Long Island. There is an emergency tie-in to the State of Maine but Maine does not normally operate in parallel; Maine is an island by itself in many respects, you see, even when it holds elections. There is an antiexport law that doesn't permit the utilities to export hydroelectric power from Maine to any state in the Union. It is the only state with a law like that. This New York-New England interconnected group, excluding Maine, had a capability of over 10.6 million kw.

Finally, there really is one particularly outstanding example of how an extensive interconnected system operates. That consists of the systems you see on the larger map, entitled, "Electric Power Systems Serving the South Atlantic and Central Areas of the United States." You will find the list of individual companies in the lower right-hand corner. (Map on file in the ICAF Library.)

This group of systems operates in continuous parallel in portions of 24 states. The best information we have on the simultaneous load shows that this group of systems in 1951 hit a peak of over 25 million kw. This is roughly twice the power of all of Great Britain. Eventually this group will be tied in with southern Illinois and Missouri. When this occurs, this group of interconnected systems will have over 28 million kw of capacity.

This group's operation is coordinated very closely. Power is exchanged back and forth between various portions. The frequency is common to all the member systems. Emergencies are taken care of by automatic supply from one or more portions to the point of need. It takes, of course, considerable machinery to accomplish all this. But it is interesting to note that this coordination is done without any corporate or special setup, without any special bureaus. It is a remarkable example of private enterprise coordinating on a very simplified framework.

In summarizing my ideas on the contribution of the electric power industry to national defense, let me pose the question: Has the power industry actually made a contribution? My judgment and belief is yes, it has made a contribution of inestimable value. While we are a great industrial nation, the greatest in the world, let us remember that we are also the greatest power-using nation; we could not be one without the other.

Today we are engaged in this mammoth and vital defense effort, in the course of which we are mobilizing all our resources. The fact that we have such power systems as I have shown you, the fact that we have carried on extensive development of these power systems, makes it possible in times like these, when we are confronted with projects of enormous scope and magnitude, to consider creating almost overnight additional power facilities running into the millions of kilowatts.

Thus, when we are asked by the people in charge of the defense program, "How about giving us 2 million kw, or 15 billion kwh, at this location?" we are able to say, "Yes! When do you want them?" And provided the time isn't too unreasonable—two years, perhaps, which is about as fast as you can put things together—we will say, "You can have this power; we will generate the 15 to 20 billion kwh needed and deliver them to you in time to meet this defense effort. We will do it with the absolute topmost economy that the human mind and brain has been able to develop. We will burn "X" million tons of coal in the process. We will tell you how long it will take to build these facilities and how much the power will cost, and we will give you this estimate accurate to within a percent or two. That is one of the things that has been brought about in this country in the power field.

We have acquired world leadership in power technology and power facilities. We have developed that leadership as a part of our fundamental system of personal freedom, part of our system of private enterprise, and in my judgment it couldn't have come about any other way.

It took that kind of system, people with that kind of philosophy, with that kind of outlook, with the great heritage and privileges that go with our system to bring this world leadership about. If it had been otherwise, we wouldn't have that development today. I think it would be a sad day for the power industry if private enterprise is ever materially reduced. And if our system of free enterprise is eliminated in the power industry, I think it would be a sad day for our entire economic system, both from the standpoint of our peacetime welfare and from the standpoint of our national defense.

Thank you.

QUESTION: A look at this map of our principal interconnected electric transmission lines gives the appearance that our electric power grid is not as vulnerable as the German power grid was if we had known that. However, in the Pacific it looks as if bombs could completely annihilate the power system up there and men could break up the system in smaller segments. I wonder if I am interpreting this map correctly and, if I am, what effect would bombs have on that area?

MR. SPORN: As you know, highly classified discussions of this general question are going on at this time. We have made a classified

study of our system just by way of determination of what the problems would be. The best means of protecting ourselves against atomic bombing of power facilities have not been determined, but in my judgment interconnected operation is one of the great defenses against it. If you are interested in that question, you will find that I gave a discussion of that subject the last time I appeared before this group; I am sure there are copies of that talk available here.

One of the important things to remember is that, while transmission systems can be knocked out, the repairing of transmission systems, even with a direct hit of an atomic bomb, is relatively simple if you have all the materials available. So, without question, one of the most important defenses of the power supply systems is going to be, as it already is, a strategically selected and well-located system of supply of materials and parts. But the call on the resources of the national economy to provide enough of this emergency power material for the entire United States would be relatively simple as contrasted even with the price of one big bomber, one B-36, let alone a B-52.

But the problems of protecting a power plant are much more difficult. There we get into quite a few questions. I would like to make this observation, and then I would like to refer you to Major Swaren to supplement my comments if he feels at all that they need it. In the last war our thinking went something like this: "The German power systems are interconnected. Thus, essentially, they are not vulnerable. We therefore won't waste our carefully obtained and unexpendable important bombers and crews on power systems. Instead we will concentrate on industries--ball-bearing plants, or other plants like that."

That was not good power system thinking. It is quite true that you can quickly repair a transmission line which has been bombed out of service. But if an area is tight on capacity and, by bombing, you take out two or three critical power plants, you are going to raise the very devil with the industrial production in that area. A power plant properly blasted can't be returned to service in a week or a month. Some of it may have to stay out several years. These considerations lead to the following kind of thinking.

What we need, therefore, if we can't provide complete protection for power plants, is to have a system by which we can bring in capacity from many, closely tied together power plants to an area where a vital power plant or plants may be completely knocked out. While we will get busy and try to repair the bombed plant and put it back on the line just as quickly as we can, we could promptly restore industrial production if we bring in power from the other sources of supply. It is a very important question on which we need to do more work. Major Swaren, would you care to supplement what I have said?

MR. SWAREN: Except to say that some people in high places who knew the power industry tried very hard to get some of the power plants bombed, but it was not until the very last, just shortly before VJ-day, that I was preparing to go across to Okinawa to set up missions against the big Suiko plants. But the attitude of the "Indians" of General Staff and the men who selected targets was just as Mr. Sporn has said. We couldn't convince them that a power plant knocked out meant knocking out production.

QUESTION: My question deals with economic production. I am quite impressed with the figures and facts you have given us and what it takes to produce a little bit of power. I assume a lot of thought has been given to how much it costs to dig down to the coal and transmit power over a given distance. We have heard the idea set forth as to the feasibility of producing power in the ground, that is the production of power from the coal while in the ground. That, as I see it, relates to the protection of the plant and the economics of production. Will you comment on that?

MR. SPORN: I am not sure I am clear as to your question. First, about the hauling of coal--we can haul coal in a half dozen ways by a half dozen means. We haul most of it by rail. We have our river transportation. Coal produced in the Appalachian coal fields is brought up to Philadelphia, New York, and Washington by rail. We can haul coal by "electric car" by building a power plant at the mouth of the mine, generating the power there, and moving the energy of the coal by electric transmission of the power generated at the mouth-of-mine plant.

Determining a fine balance between rail, river, and electric transportation is a very difficult problem. There are a large number of variables which have to do with such things as the quality of the coal, the type of rail haul, the climate traversed by the transmission lines and many other factors. For example, in some of the power plants of this country today we are burning high ash coal. Such coals have an ash content of 22 to 25 percent. If you haul that coal 200 or 300 miles, 25 percent of your haul is ash. If you have a 60-car haul, you will haul 15 cars of rock. The movement of coal, or rather of the energy of the coal, boils down to the problem of what kind of fuel and what kind of transmission you have, and whether you have the right transmission for the fuel you are trying to haul.

The cost of electrical transmission is primarily in the capital facilities. That means once you have built your electrical transmission plant, you can operate it 365 days a year, 24 hours every day, and the cost of operating is no greater if you do it that way than if you operate only 150 days a year and 10 hours a day. The total cost is the same but the cost per unit of energy transmitted is less. All these things simply mean that there are competitive, complicated factors. Different groups or organizations are all attempting to make the right evaluations, but each does a better or poorer job of making the best evaluation.

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There are in prospect, looming on the horizon, two other methods of transporting coal. One is the pipeline haulage of coal. Considerable experimental work is under way now on a process that involves pulverizing the coal at the mine, mixing water with it, and pumping the resulting slurry through the pipeline just as you would pump oil. At the other end of the pipeline you have to separate the water from the coal.

We have in prospect the possibility of underground production of fuel gas from coal. That is a technological development we have been talking about and doing some work on for many years. There is some work going on in this country right now, in Alabama. The Belgians are doing a considerable amount of work on it and we know the Russians have done a great deal of work on it.

Since this is an Army group, I thought you would be interested in a story on that. We have followed underground gasification work in my company for many years. I personally followed it for many years and up to a point thought I knew everything that was going on. Then about 1939 I found that what we now call the Iron Curtain had descended; the Russians had stopped publishing reports on their progress and we couldn't learn anything further of their work. But until that time we had the advantage of extensive publication on the work they were carrying on, mostly in the Donetz coal basin.

In late 1945 or early 1946, I went to Mr. Krug, whom I had known for many years and who had come to be head of WPB--later Secretary of the Interior--and told him of my interest. Since I knew we were giving the Russians a great deal of lend-lease material, I wondered if we might send a technical team into Russia to find out what things the Russians had done in the interval since 1938. I thought that would be only fair between allies.

Mr. Krug agreed with me. He took it up with the State Department; they took it up with the Russians; and the Russians in due course gave an answer. They thought it was a fine idea. They would be glad to entertain a team; they would be glad to show them everything that they had done in underground gasification of coal; but they thought the matter deserved reciprocity. A fair reciprocal arrangement would be for them to send in a team to go over our atomic power plants.

On the problem of fuel, I want you to remember that we are rapidly getting to the place where 80 percent of all the energy we create is going to be created by fuels, and you will find that unless and until we learn--if we ever do--how to use a nuclear fuel practically and economically, we will rely on coal. Coal is the basis certainly of our massive defense program, the defense program we are in now. The installations of the Atomic Energy Commission, for example, are being powered by coal-produced energy. That is an interesting commentary, and more and more coal is coming to be recognized as the prime source of mass-produced energy. That is the energy picture today.

MR. SWAREN: Our time has run out, Mr. Sporn. I thank you on behalf of the College for this very interesting talk on the most important subject our country has today.

(6 June 1952--350)S/VJM

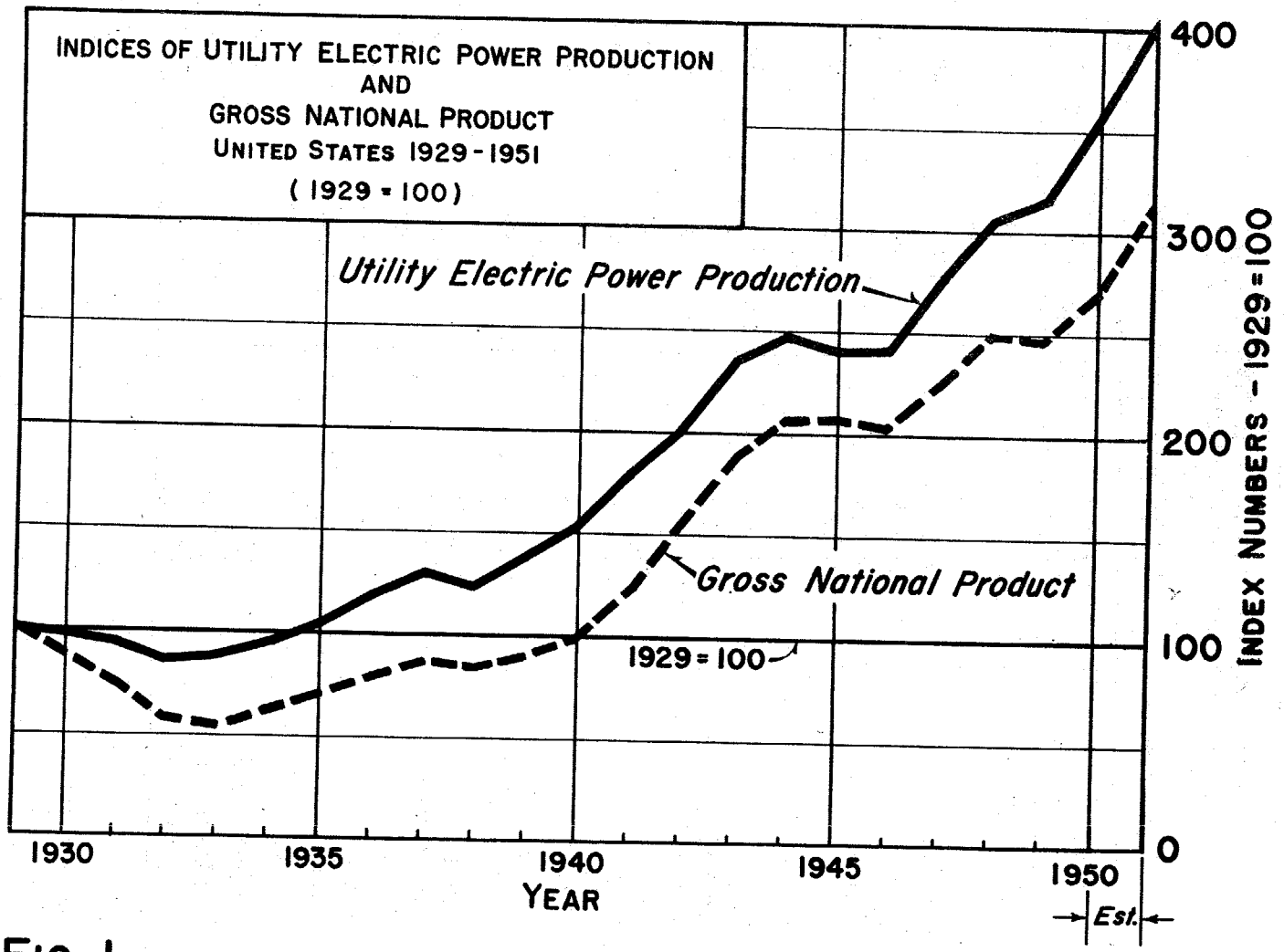

FIG. 1

January, 1952

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TABLE I

PRODUCTION OF ELECTRIC ENERGY PER CAPITA
IN VARIOUS COUNTRIES OF THE WORLD
1950

(Countries of 40,000,000 or more population underscored)

Country	Population (000's)	Kwh Produced (000,000's)	Kwh/Capita
Argentina	17,196	4,408	256
Austria	7,000	7,514	1,073
Belgium	8,639	8,484	982
Brazil	52,124	2,856	55
Canada	13,854	56,563	4,083
Chile	5,809	1,524	262
China	465,000 (Est.)	1,879 [1]	4
France	41,900	34,712	828
Western Germany	47,607	43,956	923
Israel	1,094	461	421
Italy	46,272	23,600	510
India	358,000	5,100	14
Japan	83,200	38,827	467
Mexico	25,581	4,416	172
Norway	3,265	17,328	5,338
Pakistan	75,000	131	2
Philippines	19,557	458	23
Spain	28,287	6,276	222
Sweden	7,017	18,348	2,615
Switzerland	4,694	11,150	2,375
Turkey	20,935	734	35
United Kingdom	50,616	54,960	1,085
United States	151,689	387,924	2,557
U.S.S.R. (Est.)	193,000	90,000	466

Note: [1] 1948

Sources: EEI

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TABLE 2

INDUSTRIAL REQUIREMENTS OF ELECTRIC ENERGY SUPPLIED BY PUBLIC UTILITIES IN THE UNITED STATES

1920 - 1950

Year	Total Industrial 1 Consumption (Million Kwh)	Purchases from Public Utilities 2		Industrial Generation	
		(Million Kwh)	% of Consumption	(Million Kwh)	% of Consumption
1920	36,034	18,880[3]	52	17,154	48
1925	53,095	29,880[3]	56	23,215	44
1930	63,673	40,148	63	23,525	37
1935	64,513	40,865	63	23,648	37
1940	97,627	59,557	61	38,070	39
1945	156,259	107,490	69	48,769	31
1950	252,001	193,065	77	58,926	23

NOTES: [1] Large Light and Power Sales by Utilities plus Industrial Generation.

[2] Large Light and Power.

[3] Estimated

SOURCES: EEI; Historical Statistics of the United States.

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TABLE 3

UTILITY PRODUCTION OF ELECTRIC ENERGY IN THE UNITED STATES BY OWNERSHIP

1937 - 1951

Year	Total Production	Privately Owned Electric Power Companies		Local,[1] State and Federally Owned Utility Systems	
	Kwh, Millions	Kwh, Millions	% of Total	Kwh, Millions	% of Total
1937	118,913	110,464	92.9	8,449	7.1
1938	113,812	104,090	91.5	9,722	8.5
1939	127,642	115,078	90.2	12,564	9.8
1940	141,837	125,411	88.4	16,426[2]	11.6
1941	164,788	144,290	87.6	20,498	12.4
1942	185,980	158,052	85.0	27,928	15.0
1943	217,758	180,247	82.8	37,511	17.2
1944	228,189	185,850	81.4	42,339	18.6
1945	222,486	180,926	81.3	41,560	18.7
1946	223,178	181,020	81.1	42,158	18.9
1947	255,739	208,105	81.4	47,634	18.6
1948	282,698	228,231	80.7	54,467	19.3
1949	291,099	233,112	80.1	57,987	19.9
1950	328,998	266,823	81.1	62,175	18.9
1951[3]	370,536	302,108	81.5	68,428	18.5

NOTES: [1] Includes municipals, cooperatives and power districts.

[2] 1940 and later data revised to exclude production by publicly owned transit systems.

[3] Estimated.

SOURCE: Federal Power Commission.

TABLE 4

GROWTH OF POWER USE IN THE UNITED STATES 1935 - 1951

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Year	Non-Coincident Peak Loads (Thousands of Kw)	Generation - All Plants Contributing to the Public Supply (Thousands of Kwh)
1935	21,000	95,287,390
1936	23,900	109,316,033
1937	24,700	118,912,675
1938	25,350	113,812,371
1939	28,700	127,641,804
1940	30,800	141.837,010
1941	34,650	164,787,878
1942	35,850	185,979,476
1943	40,100	217,758,831
1944	40,650	228,188,844
1945	39,550	222,486,283
1946	45,000	223,177,783
1947	49,550	255,738,984
1948	53,750	282,698,214
1949	56,500	291,099,543
1950	64,125	328,997,875
1951 *	70,500	370,536,000

NOTE: * Preliminary.

SOURCE: EEI

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TABLE 5

ELECTRIC UTILITIES' GENERATING CAPACITY, PEAK LOADS AND INDICATED RESERVES IN THE UNITED STATES

1939-1951

Year	Non-coincident Peak Loads (Thousands of Kw)	Installed Capacity Public Utilities (Thousands of Kw)	Indicated Reserves (Thousands of Kw)	Indicated Reserves, % of Non-coincident Peak Demand
1939	28,700	38,863	10,163	35
1940	30,800	39,927	9,127	30
1941	34,650	42,405	7,755	22
1942	35,850	45,053	9,203	26
1943	40,100	47,951	7,851	20
1944	40,650	49,189	8,539	21
1945	39,550	50,111	10,561	27
1946	45,000	50,317	5,317	11.8
1947	49,550	52,322	2,772	5.6
1948	53,750	56,560	2,810	5.2
1949	56,500	63,100	6,600	11.7
1950	64,125	68,501	4,376	6.8
1951 *	70,500	76,000	5,500	7.8

Note: * Preliminary

Source: EEI

TABLE 6

ANNUAL CAPITAL EXPENDITURES
FOR NEW ELECTRIC UTILITY CONSTRUCTION
PRIVATE, MUNICIPAL, STATE AND POWER DISTRICT SYSTEMS
1936 - 1952

(Thousands of Dollars)

Year	Generating Plants		Transmission	Distribution	General Plant	Total
	Fuel	Hydro				
1936	36,820	9,030	55,305	184,725	24,000	289,710
1937	113,060	10,540	100,400	223,620	38,600	455,480
1938	133,000	17,600	59,200	238,200	34,000	482,000
1939	101,500	17,900	61,375	226,375	22,850	430,000
1940	200,430	9,270	84,780	266,580	35,520	596,580
1941	219,741	27,186	101,085	272,449	32,687	654,148
1942[1]	191,671	22,847	85,633	144,180	11,644	455,975
1943	137,059	35,505	42,923	84,683	6,066	306,286
1944	96,126	19,888	61,196	151,969	11,105	340,284
1945	106,166	12,713	68,935	204,492	16,623	408,929
1946	190,955	18,974	106,550	360,980	40,710	718,169
1947	440,547	40,901	195,074	624,038	71,585	1,372,145
1948	813,025	86,188	280,530	822,275	76,070	2,078,088
1949	1,078,081	150,653	288,358	916,475	84,047	2,517,614
1950	960,739	107,730	300,093	879,242	99,367	2,347,171
1951	940,541	125,463	346,059	910,581	120,674	2,443,324
1952[2]	1,390,090	102,101	463,561	938,774	107,277	3,001,803

NOTES: [1] Electrical World survey not made in 1942. Figures are those reported by Federal Power Commission for privately owned utilities only.

[2] Prospective

SOURCE: Electrical World, January 28, 1952 (Electrical World surveys)

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TABLE 7

COMPOSITE INCOME STATEMENT OF PRIVATELY OWNED ELECTRIC LIGHT AND POWER COMPANIES IN THE UNITED STATES, 1946 - 1951

(Millions of Dollars)

	1946	1947	1948	1949	1950	1951[3]
Total Electric Revenue	3,127	3,480	3,886	4,113	4,510	4,955
Operating Expenses	1,385	1,701	2,019	2,030	2,158	2,367
Depreciation	324	339	366	389	438	480
Total Expenses	1,709	2,040	2,392	2,419	2,596	2,847
Electric Operating Income before Taxes	1,418	1,440	1,511	1,694	1,914	2,108
Taxes	639	664	716	794	948	1,132
Electric Operating Income after Taxes	779	776	795	900	966	976
Other Income [1]	130	125	119	132	147	145
Gross Corporate Income	909	901	914	1,032	1,113	1,121
Capital Charges [2]	259	245	244	267	282	307
Net Income	651	656	666	765	831	814
Dividends	466	500	499	655	626	670
Surplus	185	156	167	110	205	144

[1] Includes revenues of gas, water and steam departments and interest on securities held.

[2] Includes amortization and interest on long-term debt.

[3] Estimated

SOURCE: Federal Power Commission and Edison Electric Institute.

TABLE 8

DISTRIBUTION OF REVENUE DOLLAR OF PRIVATELY OWNED ELECTRIC LIGHT AND POWER COMPANIES IN THE UNITED STATES, 1946 - 1951

(Percentage)

	1946	1947	1948	1949	1950	1951*
Fuel	13.1	16.4	19.3	16.6	16.6	16.9
Salaries and Wages	18.5	20.6	20.4	20.3	19.9	19.9
Other Operating Expenses	10.9	10.2	10.6	10.9	9.8	9.7
Depreciation	9.9	9.4	9.1	9.2	9.5	9.4
Fixed Charges	8.0	6.8	6.1	6.3	6.1	6.0
Taxes	19.6	18.4	17.8	18.7	20.3	22.2
Dividends and Surplus	20.0	18.2	16.7	18.0	17.8	15.9
	100.0	100.0	100.0	100.0	100.0	100.0

*Estimated

.OURCE: Federal Power Commission and Edison Electric Institute.

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TABLE 9

TOTAL STEAM AND HYDRO ELECTRIC GENERATING CAPACITY
SCHEDULED FOR INSTALLATION ON PUBLIC SUPPLY SYSTEMS
OF THE UNITED STATES AND
ESTIMATED ANNUAL CAPITAL EXPENDITURES FOR NEW CONSTRUCTION
1952 - 1954

Year	Total Capacity, Kw [1]	Estimated Capital Expenditures
1952	9,500,000	$ 3,001,803,000 [2]
1953	12,200,000	3,800,000,000 [3]
1954	8,400,000	2,700,000,000 [3]
Total, 1952 - 1954	30,100,000	$ 9,501,803,000 [3]

NOTES: [1] From Report of Electric Power Advisory Committee, dated December 31, 1951, to Defense Production Administrator.

[2] Electrical World estimate (issue of January 28, 1952)

[3] Estimated by American Gas and Electric Service Corp.

TABLE 10

ESTIMATED PEAK LOADS, CAPABILITIES AND RESERVE MARGINS OF PUBLIC UTILITIES IN THE UNITED STATES

1952 - 1954 [1]

(Median Hydro Conditions)

Year	Peak Load (000 kw)	Capability (000 kw)	Reserve Margins	
			(000 kw)	(% of Peak)
1952	77,800	84,500	6,700	8.6
1953	87,200 [2]	96,600	9,400	10.8
1954	95-96,000 [3]	105,000	9-10,000	9.4-10.5

NOTES: [1] From report of Electric Power Advisory Committee, dated December 31, 1951, to Defense Production Administrator.

[2] Includes 2,000,000 kw added by Advisory Committee to utilities' estimates.

[3] Includes 4-5,000,000 kw added by Advisory Committee to utilities' estimates.

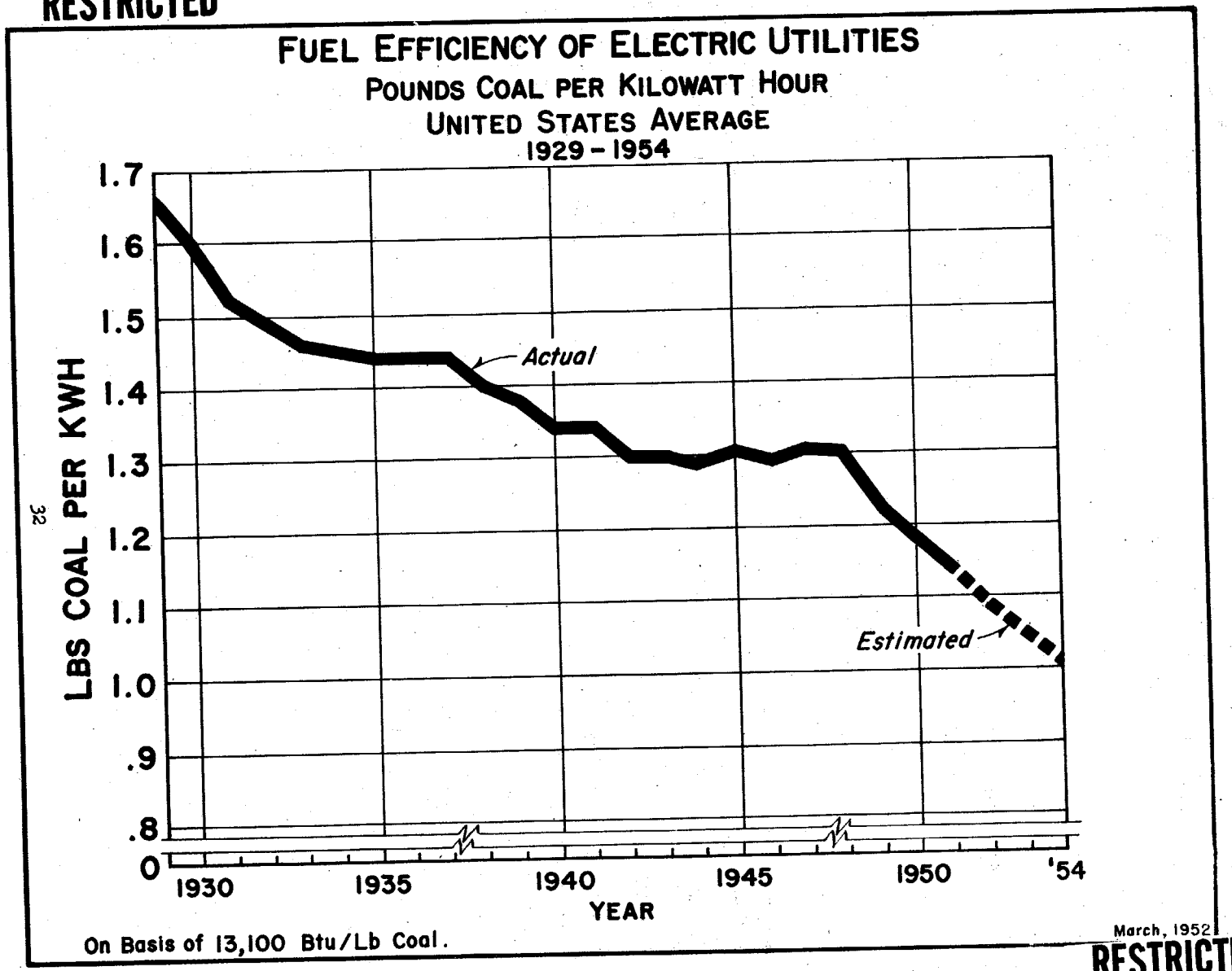
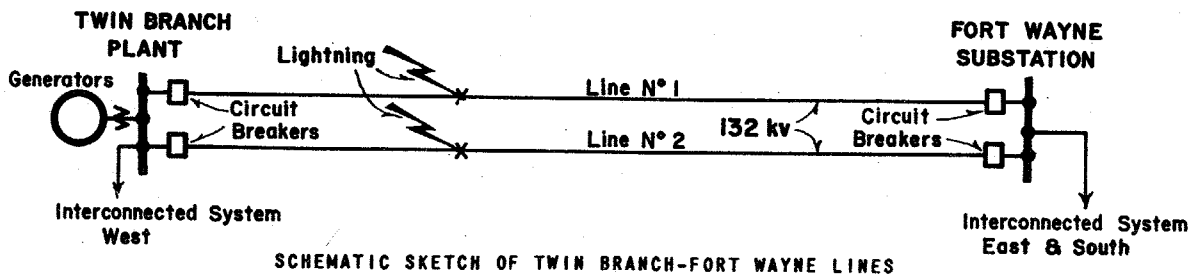
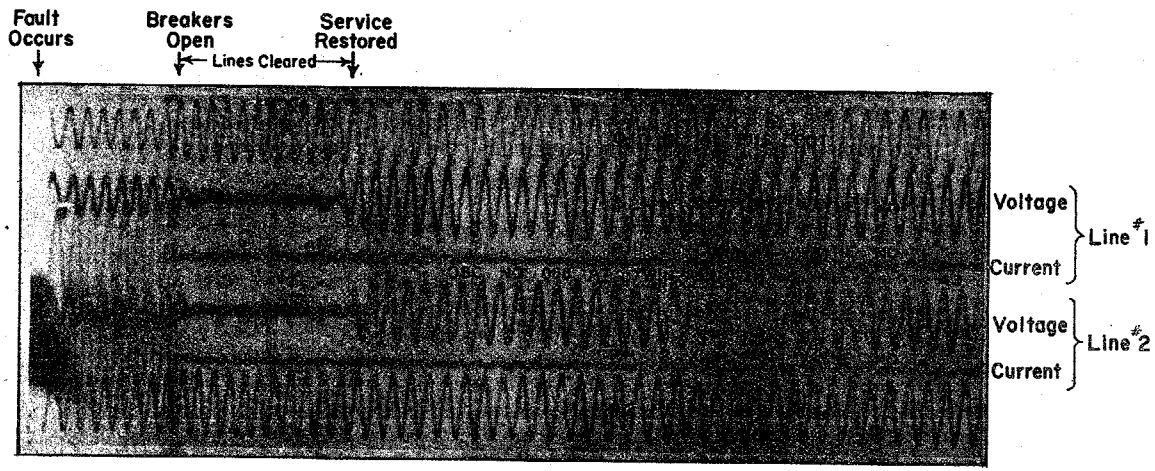

FUEL EFFICIENCY OF ELECTRIC UTILITIES
POUNDS COAL PER KILOWATT HOUR
UNITED STATES AVERAGE
1929 - 1954
LBS COAL PER KWH
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
0
Actual
Estimated
1930
1935
1940
1945
1950
'54
YEAR
On Basis of 13,100 Btu/Lb Coal.

FIG. 2

TYPICAL ULTRA HIGH SPEED RECLOSING OPERATION



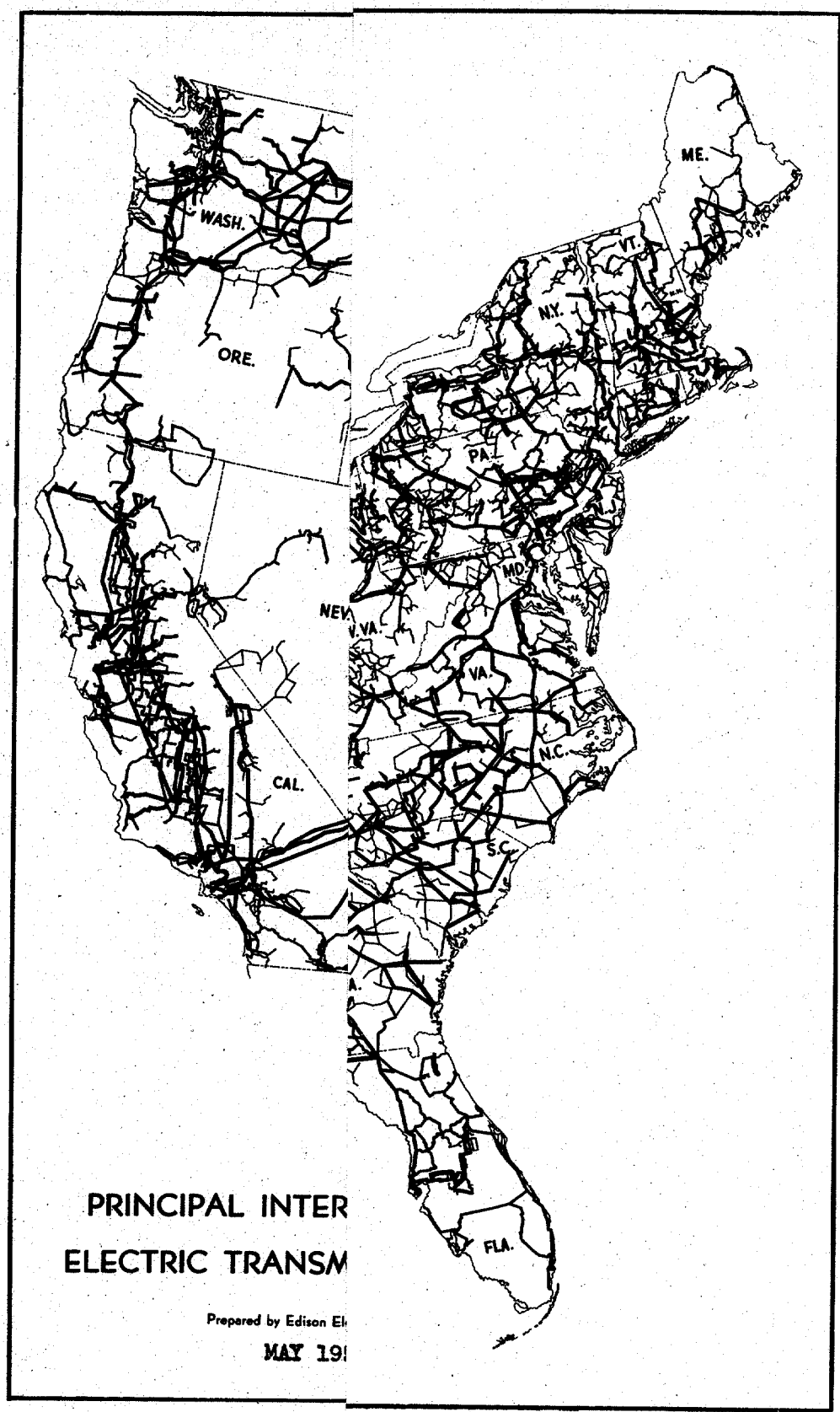
SCHEMATIC SKETCH OF TWIN BRANCH-FORT WAYNE LINES



OSCILLOGRAM RECORDED AT TWIN BRANCH PLANT

Oscillogram of simultaneous trouble on both 132-kv tie lines between Twin Branch Plant and Fort Wayne Substation. The faulty lines were disconnected in 8 cycles and reclosed 11 cycles later. During this time, both portions of the system remained in synchronism and the lines were successfully reconnected with a complete service interruption of only 11 cycles, or approximately 1/6 of a second.

FIG. 3



PRINCIPAL INTER

ELECTRIC TRANSM

Prepared by Edison El

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