ELECTRIC POWER IN INDUSTRIAL MOBILIZATION

2125

4 May 1951

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Mr. Philip Sporn is 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 Mr. 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 the brilliant 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.

ELECTRIC POWER IN INDUSTRIAL MOBILIZATION

4 May 1951

MR. SWAREN: Gentlemen: Today we have the last in our series of lectures on the power industry. These lectures have been dispersed throughout the year. It is hoped that all of you are now power conscious.

We have told you the general plan of organization of the industry. In another lecture we told you how mores of society based on customs predating history have taken the power industry in hand and bent it to the will of the Nation. From this platform you have heard discussed the nature and amount of physical structure involved in the industry. On another occasion, you heard discussed the all-important question of sources of money to finance the huge expenditures this industry requires; the revenues it obtains from its customers, and the revenues it contributes to the various government entities that administer its service areas.

Today we want to tie all of these factors into one unit; what is the contribution this industry can make to our armed strength?

We felt that a member of the industry should prepare and deliver this final package. But who, and where, is the man fitted to undertake the task? What qualifications must he have?

First of all, he must have the skill and integrity to command the respect of the industry. Second, he must know well the fundamental sciences on which the industry is built and, as an engineer, be capable of judging their application. Next, he must be an able administrator, held in affectionate respect by his subordinates and his colleagues. And last, but far from least, his counsel where men meet for decision must be sagacious.

Our speaker of today meets all these criteria. He holds so many titles and fills so many jobs as a busy citizen of the Nation that their recountment would be superfluous.

He has given generously to the Industrial College as a seminarist, in the matter of office interviews, and as a lecturer. I deem it a great honor to welcome to the platform again Mr. Philip Sporn.

Mr. Sporn.

MR. SPORN: I want to thank Mr. Swaren for his very kind and gracious introduction. Gentlemen and ladies:

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The Importance of Electric Power in Industrial Mobilization

The importance of electric power in the industrial mobilization of a country as highly industrialized as the United States has been fully recognized by almost every student of the country's economy. It was definitely recognized by the Armed Forces of the United States following the experience of World War I. One has but to examine the tabulation and curve, table 1 (page 18) and figure 1 (page 19) respectively, to see the close and intimate tie and relationship between the Nation's industrial activity, as reflected in gross national product, and its electric energy output--a relationship so close that with some minor fitting one curve can almost be substituted for the other.

And that is what one would expect. In a modern industrial society electric energy enters into every step in any representative industrial process, starting almost with the construction of the most preliminary of the final facilities needed for production and ending up with the operation of these facilities at some control center. Thus, whether the operation is one using almost negligible quantities of electric power, such as is the case with the production of wearing apparel, or whether it is one that uses very heavy quantities of electric energy such as are involved in the reduction of aluminum or magnesium, this single factor is common to almost all industrial operations; they cannot be carried out at all without some definite amount of electric energy, small in many cases, but quite large in others.

Yet it is surprising how much misunderstanding exists as to the true economic role of electric power in most industrial operations. If you will examine table 2 (page 20) showing for 1947 an analysis of energy utilized, cost of electric energy, and percentage of cost of the energy to the total value of products shipped for 20 different major industry groups, you will see the startling situation that on the average electric energy represents less than eight-tenths of 1 percent of the value of products shipped, and that only in a single case out of 20--stone, clay, and glass products--is the percentage as high as 2 percent. These figures do not apply to certain special industries utilizing electric energy as a major element in production; they are particularly not valid for electrochemical and electrometallurgical processes such as reduction of copper, zinc, and aluminum, the production of alkalis and chlorine, electric steel, and ferroalloys. Here, as will be seen from table 3 (page 21), electric energy enters into value of products to as high a percentage as slightly over 12 percent. As a matter of fact, although the exact figures for aluminum alone are not available, they probably approach a value of close to 16.5 percent.

Yet no greater mistake could be made than to fail to properly appraise the effect of electric power on the productivity of a country. The high productivity of the United States, that is the high output per unit of population, is due to a number of causes, and among the most important

are the two following: (1) the large industrial plant that is available to every worker engaged in industry, and (2) the equally important and large amount of electric power that is available for operating the industrial plant; or, to put it otherwise, that is at the beck and call of every worker engaged in operating the industrial plant. If you will examine table 4 (page 22), showing the energy production per capita per year for most of the principal countries of the world, you will find that this last figure, with some modification, can almost be taken as a direct index of industrial productivity. Thus, the pitiable figure of kilowatt-hours per capita per year for Pakistan, China, and India are not surprising when one considers the low state of their industrial development. The converse of that is equally true and even more important. In order to maintain productivity it is essential that the energy (and that of course means the machinery utilizing this energy) be made available to the industrial system.

Electric power then, when one is engaged in mobilizing the industrial resources of the United States, is highly important, but it is necessary to recognize that its critical importance comes in when it is deficient or totally unavailable. That, incidentally, has a most significant bearing on the importance and weight given, or which should be given, to the assurance of the continuity and the full availability of its supply; because electric power is so critically important and because it represents so small a percentage of total value of product, it is possible, with relatively small, if not almost negligible, diversion of material and limited national manpower, to assure its continuity and full availability. Only thus can one be certain that the whole program of mobilization will be carried along to completion according to plan and with the utmost dispatch, and at almost any level of volume that the other resources of the country outside of power--that comes down basically to material and labor--can make possible. In short, while electric power can be critically controlling by absence or even deficiency, it need not be if there is a proper and understanding evaluation of its role in industrial mobilization.

Electric Power in Special War Industries

In recent years there have developed many special war industries in which power plays an even more significant role than it does even in such items as reduction of aluminum or magnesium, or in electric steel. This is the case with such operations as the diffusion separation plants at Oak Ridge, and those in process of construction at Paducah, and in other nuclear processes in a less-advanced stage of technical development which are now also under construction, and in such important activities as the research work carried out in some of the more modern and more advanced wind tunnel laboratories. These last two operations, however, except for the fact that power plays a very vital part in their functioning, have otherwise, even from the power angle, nothing else in common; the former operation, as a general rule, requires rigorously continuous and uninterruptible power,

whereas the latter, a wind tunnel operation, can operate not only in off-peak periods, but is not critically affected by an interruption in supply, or even by the complete unavailability of power over some relatively long interval.

Means of Serving

The source of power used by American industry is predominantly the public power systems, that is, the supply systems of the public utilities. This is brought out sharply by table 5 (page 23) showing the change in pattern of supply of the industrial requirements of electric energy in the United States over the three-decade period 1920-1950. Striking in this connection are these facts:

Not only has the percentage of electric energy consumption of American industry furnished by the public utilities increased from 52 percent to 77 percent, while that generated by industrial plants has declined from 48 percent to 23 percent, but this took place in the face of an increase in annual use by industry in the three-decade period from 36 billion kw.-hrs. in 1920 to 252 billion kw.-hrs. in 1950. Thus, while the total kw.-hrs. furnished by industry itself increased from 17 billion to 59 billion, an increase of some 240 percent, the amount furnished by the utilities increased from slightly under 19 billion to 193 billion, an increase of over 900 percent. It is quite apparent from this tabulation also that this trend is moving heavily in the direction of the further increase of the percentage supplied by the utilities. Thus the problem of supply of energy to industry becomes a problem of maintaining the capability of the electric utility systems to supply the expanding industrial requirements and this will become more and more fully valid as time goes on.

Mobilization of Power Resources

To carry out effective industrial mobilization it is obvious, therefore, that mobilization of the power resources of the country's electric utilities must be carried out at the same time. Looking at the power question from a mobilization standpoint, what is the status of power resources of the United States at the present time? Fortunately, there is very excellent information available to answer this question. For this purpose we have compiled a series of interesting tables that deserve critical study and analysis.

The first of these, table 6 (page 24), shows the installed generating capacity for the 16 years 1935-1950, both on the systems of the public utilities and in other installations. Noteworthy is the fact that the increase in capacity in the decade 1940-1950 on the systems of the public utilities was over 28.5 million kw., an increase of over 71 percent, and in other sources, mostly industrial plants, the increase was almost 3 million kw., an increase of over 26 percent. This made possible an increase in total energy generation in that decade of close to 208 billion kw.-hrs. or an increase of over 115 percent. That is quite an increase in the energy resources of the country.

Table 7 (page 25) considers the utility portion of the total power supply and shows the maximum annual peak demand met by the public utility systems and the energy thus generated. Note here that the increase in demand on the public utility supply system in the same decade interval was over 33.3 million kw. or an increase of 108 percent. Energy-wise the increase was even greater, being over 187 billion kw.-hrs. or an increase of 132 percent.

Table 8 (page 26) is, I believe, particularly important and significant. This shows the maximum annual peak demand and the installed capacity on the public utility systems of the country for the period 1939-1950. In it, I have taken the difference between the installed capacity and the noncoincident peak loads and I have termed it the indicated reserve; this is shown both in absolute values and as a percentage of the annual peak load. Note here that in 1939, the year when the defense program of World War II began in earnest, the indicated reserve on the public supply systems of the country was over 10 million kw. or 35 percent of the noncoincident peak. As the defense program gathered momentum and, later, as our industrial potential began to assert itself in the final year of the war, the power demand--in 1944 for example--climbed to a figure of approximately 40.7 million kw. This was an increase of more than 41.5 percent over 1939; at the same time the reserve dropped to 21 percent. This brings out forcefully a number of fundamental points in connection with the mobilization of industrial resources: how the increased electric peak demand connected with mobilization is met initially; how it is met subsequently; and how one can, and should, take advantage of this in properly planning electric power facilities as part of an industrial mobilization program.

The Fundamental Basis for Serving Initial Mobilization Loads--WR^2 Function of Reserves

There is a very interesting parallel in this connection that can be drawn from an analysis of how increased peak demand on a system of power supply is met from instant to instant in the operation of the power system. Starting with the assumption of a system operating in complete balance, at exactly proper frequency, so that no generating source is being called upon to increase or decrease generation in order to either accelerate or decelerate the entire power system because frequency is either too low or too high, we have a condition wherein the amount of power generated is exactly equal to the amount of power consumed. This perfection of balance is fundamental to an electric power supply system; there is no possibility of generating slightly in advance of or slightly behind the demand. How then is the increased power generation taken care of when a new load is thrown on the system--when it is done, for example, by an electronic switch in a matter of possibly microseconds? As a general rule such increased demand is always met but, since the additional power is not being generated when the switch is thrown, where does the power come from to supply the increased demand after the switch is closed? The answer is, of course, that it comes from the system inertia--the WR^2 or

flywheel effect of the entire system operating in synchronism. Initially, enough power is supplied through this loss of system flywheel effect to take care of the entire increased load. In the meanwhile, as soon as system speed drops, the governors on all the prime movers of the system begin to function, and more water or steam--depending on whether they are water or steam turbines--is admitted to the turbines operating on the system to not only supply the new load but to make up for the system's loss of speed and to bring back system speed to normal. This may involve several overswings in both directions. But essentially it is the system flywheel effect that acts as the instantaneous reserve in system generation; it is the flywheel effect which makes possible the immediate and instantaneous first response of a power supply system to additional load thrown on the system.

The reserve capacity has somewhat the same function in initially meeting demands of new loads--particularly demands coming on at a faster rate than new capacity can at first be built. Reserve is provided in the first place to take care of emergency or abnormal conditions brought about by failure of plant or equipment. In addition, under normal conditions there is a small fraction of the reserve margin that has been allocated to expected load growth which must be met faster than new capacity can be built. However, when confronted with a major program of industrial mobilization, the amount of new industrial load which may have to be supplied faster than new capacity can be built will be appreciably larger. The function of the reserve is still to pick up that additional load as fast as it comes on, even at the expense of normal reserves, and for the system to continue on a diminished reserve basis until reserves can be brought back to the safe minimum under mobilization conditions. This latter minimum may very well be appreciably lower than would be considered wise under peacetime conditions; the reserves normal to peacetime conditions would presumably not be re-established until the end of the mobilization period, or until a peacetime condition was reached.

With these observations in mind it may be profitable to take another look at table 8. It will be noticed that not only did the power systems of the country function in harmony with this principle during the emergency period 1939-1945, but they continued to function closely in accordance with the same principle over the next five years. Thus the drop in reserves to 11.8 percent in 1946 was brought about primarily by the wholly unforeseen and unexpected snapback of electric demand following VJ-day; this in turn was followed by the postwar boom of 1947 and 1948 and by an increase in rate of growth of electric demand wholly unexpected and unpredicted by all students of the country's economy in 1945 and early 1946 when the power generation program for the two years 1947-1948 was originally set up by the War Production Board agencies. Hence, though loads were met in these 2 years, margins of reserve dropped to values of 5.6 and 5.2 percent--far too low. By 1949 the reserves were brought back--mostly by post VJ-day planned capacity--to a figure of 11.7 percent; this was scheduled to rise to a value above 15 percent in 1950, and it would have done so had the country not been compelled to initiate the second mobilization program

within a decade. But note how, in dropping to a value of 6.8 percent in 1950, reserves played their proper function here once again.

It may be instructive to examine the load and capacity situation of the United States as it appeared as of approximately the first of April and particularly in the light of the discussion of the function of reserves just developed. Table 9 shows the generating capacity scheduled for completion on the public utility supply systems, both public and private, for the years 1951-1954. As to the first two years of this period, the capacity scheduled to be installed can without question no longer be increased. There is a possibility that at least some small amount of additional steam capacity can be scheduled for 1953; and as for 1954 the relatively small amount of steam capacity scheduled so far, is obviously only a small percentage of what will ultimately be committed for if the mobilization effort continues to develop. But disregarding 1954, the interesting fact is that for the years 1951-1953 a total of some over 25.9 million kw. of new capacity is scheduled to be installed, representing roughly 40 percent of the total noncoincident peak demand experienced by the utility systems in 1950.

The situation that these capacity additions will create as regards reserves is shown very well in table 10 (page 28). Thus it now appears that on the basis of the first-of-April figures a total reserve margin of about 5.7 million kw. above noncoincident peak demand will be available by the end of 1951; this will increase to approximately 13.7 million kw. by 1954. Percentagewise, the reserve margins are estimated at 8.3 and 15.7 percent of peak demand for 1951 and 1954, respectively. Under adverse hydro conditions these figures would be slightly lower, but not enough to substantially change the picture. Thus, here once more the reserve, which in playing its functional role went down to 6.8 percent in 1950, will be brought back to close to 16 percent by 1953. This is a level above which it unquestionably should not be projected in times of high industrial activity.

An important element in the effective ability of power supply systems to meet the mobilization demand of a highly industrialized economy is the improvement in load factor that can be expected and that must be encouraged during times of mobilization. That this not only is possible, but can effectively be brought about, is demonstrated clearly in table 11 (page 29). Here are shown, for the period 1939 to 1950, the increases over the preceding year for the public supply systems in peak demands, energy generation, and in the annual load factor on the increased demand and on the system demand as a whole. The most interesting figures here are those in the last two columns. It will be observed that the load factor on the increased demand which was 47 percent in 1939 went up to 216 percent by 1944, this in turn being reflected in the system load factor increase from 50.8 percent to 64.2 percent, an increase of 13.4 points or over 26 percent. Since as a general rule industrial production will be in proportion to energy used rather than peak demand established, it is significant that so much greater

energy production can be obtained from a power system under full mobilization conditions than what one would expect merely from a straight projection of capacity available if utilized at the lower load factors prevailing just before mobilization commences.

Effect of Integrated Systems on Power Availability

It must be apparent that in discussing power supply from a national standpoint, and in developing ideas and figures on reserves on a national basis, there is a possibility of both fallacy and error due to the fact that the power facilities of the country are not all part of a single system. That is, they are not all integrated and are not operating as a single system. It is possible, therefore, under a condition where an over-all reserve of 10 percent, say, is shown, to have an actual capacity deficiency at one point and a reserve considerably greater than 10 percent at another point--and, of course, the deficiency point is not helped by the more than adequate reserve available at the other point. This cannot happen within the confines of an integrated system. It may be worth while, therefore, to comment on the integrated system. This unfortunately, is not the place, nor is the time available for a well rounded discussion of the integrated power system, interesting as that might be. I would, however, like to make an observation on one aspect of integration: Not only can the integrated system, properly designed and operated, supply a given area or a given amount of power with a minimum call upon limited resources in materials and manpower, but it has the great advantage that within the integrated area a substantial portion of the total system power supply resources can be mobilized at and made available to any point on the system.

Thus, the development of new operations or processes at any point in an area, calling for even major quantities of power on relatively short notice, is materially facilitated on the integrated system because the power can be brought into such a point more quickly than would otherwise be possible. Not only is this of vital importance from the standpoint of time, but the fact that it can be brought in most economically is of equal importance since, during times of emergency, materials and manpower are invariably also critical.

Illustrative of this point, I would like to call attention to the map, figure 2 (page 30), showing the main transmission system lines of the American Gas and Electric Company System. That system, serving an area of some 90,000 square miles in the seven states of Michigan, Indiana, Ohio, West Virginia, Virginia, Kentucky, and Tennessee, had a one-hour maximum demand of 900,000 kw. in 1939. The demand on the system last year was approximately 2.4 million kw. It is, of course, as I am sure all of you are aware, located in the very heart of one of the major, if not the largest, defense areas of the United States. It now appears that the one-hour peak demand on that system in 1954 will be 3.4 million kw. The major transmission network of the system is at the present time operating at 132,000 volts but there is now being developed a new network which will

operate at 315,000 volts. Nevertheless, areas of considerable extent are reached by voltage no higher than 66,000 or even in some cases as low as 33,000 volts. A study--carried out some time ago--of 100 typical communities distributed from one end of the system to the other where loads of relatively low level of demand were then being served indicated that no difficulty would be experienced in supplying economically an increase in demand of 50,000 kw. to any one of the 100 points. (These points are shown in figure 2.) In a number of these communities increases in demand of that order are now being realized due to the development of new defense loads.

Assuring Continuity of Supply Under Grave Emergency Conditions

No discussion of the problem of electric power in industrial mobilization in the atom bomb age would be complete without at least briefly touching upon the basic question of power supply under the threat of atomic bombing. I would like to say at the outset that I doubt that all the phases or all problems entering into a complete consideration of this complex question have as yet been studied through; we do not, in fact, as yet know what all the basic problems are. Nevertheless, a number of points seem to be quite clear:

1. It is not possible to prepare comprehensive mobilization plans without adequately answering the question of protection of the power supply systems under atomic attack. It needs, therefore, to be studied and completely resolved.

2. In any study of the effects of atomic bombing on a power supply system, the first question to ask is what magnitude of damage can be expected to a power plant or a substation serving or supplying an area, and what will be the effect both on equipment and personnel. Here the two factors which need to be considered are the blast effect and the heat effect. The damage resulting from blast will presumably depend on the nearness of the bomb explosion to the facilities being considered. The heat, while very intense, is of very short duration and there is no stored effect. There has been some opinion expressed that a wall would keep the heat from penetrating inside a building. On the other hand, if the blast breaks windows or caves in walls, is it not plausible to assume that the heat would follow through and cause additional damage? For example, would the heat be sufficient to char or melt the relatively small amount of insulation on control wires, or to burn or otherwise materially damage the much thicker insulation on generator windings? It is conceivable that the maximum damage would be only in control and that a turbogenerator would not be damaged at all unless a major collapse of the building took place.

3. The question of the extent of the area of bombing to be assumed is very important in any reasonable study of the problem. It is clear, for example, that it would be easier to put out of commission a

large percentage of the generating capacity on a relatively concentrated system, with all the generating stations located within a limited physical or geographical area, than to inflict the same damage to a widespread system. Under similar conditions of attack strength the widespread system would not only suffer less damage, but would offer greater opportunity of bringing spare parts and materials from the other stations into the damaged area.

4. In all of the above no thought has been given to operating personnel. In many cases a substantial percentage of the operating personnel lives within a relatively short distance of the power plants. It is obvious that such people would be materially affected. On systems where this condition prevailed, it might critically affect ability to restore service. However, if bombing were not suffered over too extensive an area, in the case of less concentrated systems--and certainly in the case of systems integrating a wide area extending, perhaps, over thousands of square miles--it would be reasonable to expect that the damage, including damage to personnel, would be confined to one or two plants. Here, therefore, the problem of drawing in personnel to a damaged plant from the remaining plants would be much simpler.

5. If the problem is to be tackled rationally, some of these questions need to be answered; but once we know or can assume the effects of atomic bombing at various distances from ground zero, an intelligent discussion of service restoration becomes more simple. However, for any system, extent of damage, particularly of turbine room and boiler room facilities, is without question one of the critical items or assumptions on which additional information needs to be gathered. If damage can be assumed to be no heavier than breaking of piping connections, cracking of turbogenerator shells, or of heat exchanger equipment, then unquestionably damage repair--particularly with an adequate, safely stored supply of spare parts and repair equipment--would be a relatively easy affair and could be accomplished, with full service restored, in a very small fraction of the time that would be involved if major structures were either crippled or twisted or otherwise structurally affected to the point where repair is substantially impossible except by a complete replacement.

6. From all of this rather incomplete examination of the question it would appear that extensive and substantial interconnections would play a very important part in assuring that power is available or would be made available to important industrial areas that suffer atomic bombing damage. Thus, a preliminary study made of the American Gas and Electric Company System indicates that by blocking load, close to one million kw. of capacity could be brought in through interconnections to make up the loss or almost complete destruction of the two largest plants on the system. I want you to imagine a block at New York City--how much industry would be taken care of by a million kw.; or, conversely, the effect if it were not available.

7. The suggestion has been made that portable power plants might be an answer to the question of restoration of service or assurance of service in case of atomic bombing. The portable power plant, however, demands so much in the way of resources from an already extended national economy to supply a kw. of capacity that it is highly questionable whether, except in times of great depression, any diversion of critical materials, facilities, or manpower could be justified to the solution of the atomic disaster problem through this route. If portable equipment has any justification, it would appear to be rather in the field of such equipment as transformers or possibly switch gear. A well-thought-out program along these lines backed up by a well-stocked supply of emergency materials, functioning over a network of adequately interconnected transmission facilities, would, it is believed, do more per unit of effort or resources to assure continuity of supply or restoration of interrupted supply, than anything else that could be done, in times of mobilization such as the one we are now going through. Here again, interconnections between systems can be made most effective if the interconnected systems are completely integrated, because it is only on integrated systems that the maximum mobilization of reserves, or facilities in general, available to a system, can be made at any point--such as an interconnection point with another system.

All these points constitute an admittedly inadequate discussion of one of the very important questions in a well-rounded mobilization program. Fortunately, a great deal of thought is being given to the question of electric power supply at the present time. I am hopeful, therefore, that out of it a much clearer, and more satisfactory, answer will be worked out.

COLONEL VAN WAY: A question came up during the break about table 2 in columns 2 and 3. You will notice that there is more purchased than generated. It seems rather odd that this should happen; so I have asked Mr. Sporn to explain that as the start of the question period.

MR. SPORN: "Generated" there means "generated in captive plants." The total sold is given there as 5,811 x 10^6 kw.-hrs. and the total energy used is 140,000 x 10^6 kw.-hrs. In other words, that ratio of 43 to 140 shows the percentage of total energy used and generated by industry itself.

QUESTION: I was wondering what the highest practical limit is on high-voltage operation on long-distance lines. Associated with that question is this: What progress do you think will be made in the transmission of direct current in the next two or three decades?

MR. SPORN: About three years ago we initiated a very elaborate high-voltage research program on our system that we call the Tidd Extra High-Voltage Research Project. In it, we tried to work out both the technical and the economic problems which had to be solved before we had an adequate answer to the questions posed by high-voltage transmission. We carried out experimental work up to 500,000 volts.

There is no question that we know how to build the equipment that will be able to stand up to 500,000 volts. There is no problem of finding the conductors or the insulators that will insulate against that voltage. The problem, as we finally shook it down, is primarily a question of economics plus one problem which at this time looks quite formidable. Maybe as we go on, it will not be so formidable. That is the problem that can be called radio influence, or, in simple language, you can call it interference--primarily with television.

That in turn depends upon where we are going to build the line. Strangely enough, if your line is going to come in a concentrated center of population, the problem is less acute than it is in a relatively sparsely settled area. The reason for that is that the level of reception you get in a large center of population is much higher, and the amount of amplification, which always results in interference, is therefore much less than in the sparsely settled areas.

We used the results of our research as the basis for making a decision as to what voltage we ought to set up for the new transmission network which we thought we had to develop at a much higher voltage than the one on which we had been operating. The original network was started in 1916. We reached the conclusion that the new network voltage ought to be 315,000 volts. We have quite a number of lines designed for 315,000 volts now under actual construction; incidentally, we expect to have good chances of operating these lines at a voltage up to 345,000 volts.

The Swedes are building some lines to operate at 380,000 volts. They have some very difficult problems in bringing hydroelectrically generated power out of the Arctic, transmitting it such a long distance. We are watching them very closely. We think they are doing a pretty fair job, but we are not duplicating the kind of work they are doing. But they have a sound basis for what they are doing. The first of their high-voltage lines is not in operation yet, but will be in operation probably within the next two years. It will, as I said, carry 380,000 volts.

You asked me what will be the limits for transmission in the next two or three decades? I do not think we will have it up much higher than 400,000 volts in the next three years. Beyond that I wouldn't attempt to say.

As to direct current transmission, most of the development work on it has been discontinued. In the last four or five years we had reached the point, both in this country and in Switzerland--where a great deal of work had been done on it--where it is quite apparent that, except for one or two rather tough technical problems, direct current lines could be built and probably operated quite successfully.

There was only one technical problem left and it is a most important one, that is, how to build a direct current circuit breaker. You have to remember that in an alternating current of 60 cycles, the electric current goes through a point of zero voltage 120 times every second. It is at that point you can stop the current very easily. In fact, all circuit breakers depend upon that principle. If you interpose something in the way of continuous flow when the current is at its weakest, you can easily stop further flow. But direct current has no zero point. Nobody has yet, therefore, found a way of interrupting a high-voltage direct current successfully except with an awful lot of work.

The problem of interrupting a high-voltage direct current has not been solved, but then there has not been any need for solving it. The reason there has not been any need is that when you work it out, it becomes quite clear that from an economics standpoint, the alternating current is much more advantageous. Because of the economic handicap of direct current transmission, the developments of long-distance transmission that are now being constructed are all being done with alternating current. It is a straight problem of economics.

QUESTION: This question may have a few things wrong in it; but, as I understand figure 1, the purpose of that is to show the parallelism between the electric power production and the gross national product.

MR. SPORN: Yes.

QUESTION: It shows that there is a very close relationship. But it seems to me that part of this power production is also part of the gross national product.

MR. SPORN: Yes. But it is a very small amount.

QUESTION: I was wondering if it wasn't rather increasing since the postwar period.

MR. SPORN: No. When you consider, for example, that in 1950 the total electric revenue of the utilities of the United States was around 5 billion dollars and that of General Motors for last year was over 7 billion dollars, you can see that the total value of electric service, and its contribution to total gross national product, is really very small. It is only because every time you do something that results in production of goods in industry, you use electric power that you think of it as large. I think most economists recognize that there is not a single item of activity that is as good a barometer of the over-all industrial activity--in the United States, at any rate--as electric power. If you watch the national figures on electric power, you can tell what is going on industrially in the country. That is the point of that figure 1--just to show the very tight relationship between electric power production and gross national product.

QUESTION: Table 4 indicates the production of electric energy per capita in various countries of the world and shows that China, India, and Pakistan have a very low production. What does that mean when you compare it with the United States?

MR. SPORN: Please remember that by this table I did not mean to draw anything more than general conclusions. The general conclusion that I draw is something like this: That there is no question that the state of industrial production of electric energy is critically low in China, India, and Pakistan and some of the other countries.

Now, when you compare the United States, for example, with Norway, please remember first the relatively small population of Norway. Then, if you consider the number of heavy energy-consuming industries concentrated in Norway and consider the availability of cheap hydroelectric power, you can understand why the per capita figure for Norway is so high.

Then if you examine the economy of other countries, like Pakistan, you can see what is wrong there. The trouble is that in those countries the source of power is human beings. They are using human beings as horsepower, and you know what the average human being can do. If he works to the point of exhaustion, if he is at the actual top point, the best he can produce in 12 hours is something like one kilowatt-hour. In industry that is available for about three mills in some sections of the United States. You can see the trouble with those countries by just driving along the highways. You will see people operating little treadmills, pumping water. That is all they do. They don't perform very much work. In 12 hours they generate about seven-tenths of a kilowatt-hour.

That is the kind of low productivity that we have to think of in our Point 4 Program. There are a lot of arguments in favor of Point 4. I am sure it is going to do a lot of good. But in trying to implement it, we are confronted by the kind of problem that I have just described--bringing up the productivity of a country that is now at almost point zero.

QUESTION: We have heard that the cost of production of thermal power has constantly slumped. What is your prognosis for the future? What further reduction can we look for, and what are some of the factors?

MR. SPORN: That is a very good question. When I was studying power in the engineering school about 35 years ago, we thought that a thermal efficiency of 13 percent--where you got 13 percent of the energy out of a pound of coal and converted it into useful energy, was about the top in efficient performance. The best illustration of a then efficient way of getting it was the multiple-expansion engine. There were only a very few kinds of loads that could operate under that ideal cycle and give you that kind of performance.

Now, going back, for example, 40 or 45 years, I have examined records in the history of my own company that show that in 1906 in our noncondensing boilers we were using 10 pounds of anthracite coal at Scranton, Pennsylvania, to make one kilowatt-hour. The best performance that our engineers were able to get then was between 100,000 and 120,000 BTU's per kilowatt-hour. Now we are getting close to 9,000.

It is possible to better that somewhat when you go to a mercury-water cycle. But our own performance is based on an essentially straight steam cycle. With it we are getting a thermal efficiency of about 38 percent.

What you asked was what the chances are of improving that efficiency. I think they are very good, if you look at the problem in the proper perspective. The chances are that the best place for finding that additional thermal efficiency is in the higher temperatures. When you try to go to the higher temperatures, you find that right now the limit is metallurgical. We actually, less than a year ago, projected a plant, in fact, two plants, to operate at 1100 degrees F. Then we changed the specifications from what they were at that time, because we ran into critical conditions on columbium, which is one of the very tight materials. We decided to back away, because the amount of columbium we needed for 1100 degrees was about twenty times as much as we needed for 1050. For 50 degrees difference we needed twenty times as much columbium. So we backed away, not being sure that we could justify the diversion of so much critical material.

Now, one of these days, or years, I hope we are going to get out of this present condition and that we will be freer again to explore higher temperatures. We may make some progress in developing higher temperature materials which will permit us to operate even above 1200 degrees--perhaps even at 1300 or 1400 degrees.

QUESTION: I would like to ask a companion question. We have read and discussed this question of hydroelectric power. On one side there are people who say that hydro power is cheap, and on the other side there are people who say that, when you consider the construction cost of hydro power in relation to the generated power, it is not cheap. Would you care to discuss that briefly?

MR. SPORN: Hydro power is only cheap if you take into account that with some hydro power the operating costs are low. I don't know of any way in terms of the national economy of making an evaluation of the net economic cost except by using the dollar sign as the basis. You have to remember that the dollar represents an evaluation of both the labor and material costs. If you put in the proper carrying charges on the capital cost, you have a proper evaluation on a day-to-day basis. On that basis there is a good deal of hydro that simply will not stand up against steam. There is some hydro operating today, built in the past, that is much more

economical than the best steam we can build. On the other hand, there are some new hydro plants that would have a tough time competing with the kind of fuel-generated power that we had back in 1941.

In the last war I worked out some projects for the WPB in gas-fired plants. At that time we had available gas at 3.5 cents per thousand cubic feet. That is equivalent to 3.5 cents per million BTU. If we could use that gas today, if it were available--and I don't think it is any longer--or if we could get gas for 6 or 7 cents and use our thermal efficiency of around 10,000 BTU's--we are doing very close to 9,000 today in our system--we could produce a kilowatt-hour at six-tenths of a mill for fuel cost. That is very cheap power.

Obviously, a gas-fired plant can be built at a minimum expense for construction. You have no coal-handling facilities, no pulverizing equipment, no ash removal equipment. All that results in a tremendous economy over a coal burning plant.

The problem really comes down to a very complex engineering-economic question. It is most difficult to give a general answer to that question. There are many places in the United States where there is no question but that, if you are interested in terms of the national economy--and that is particularly true in times of emergency, when the needs of national safety demand getting the maximum results from a given amount of effort in material and manpower--steam will be the better answer. There are other places where hydro is better. I am sure that there are still undeveloped projects on the Columbia River that are good in an economic sense.

The reason that hydro power is generally so successful on the Pacific Coast is the high cost of fuel out there. Fuel is a tough problem in the Northwest. But hydro would certainly not be the answer to the power question in Ohio or in the coal fields of West Virginia or of Kentucky.

QUESTION: Can you say a little something about industrial and residential heating?

MR. SPORN: That is popularly known as the heat pump. The heat pump is nothing new. It is just a new way of using an old device. That device is the standard compressor circuit that you have in your refrigerator. It takes heat out of the interior of the refrigerating chamber and absorbs it by the evaporation process of the refrigerant. The evaporated refrigerant is then compressed by the compressor, thus raising its temperature. It is now condensed into a liquid and in that process gives up its heat to the outside air. What you do there is to take heat at a relatively low level from your freezing chamber, maybe at 10 degrees or at some temperature of that sort, and by putting the refrigerant under compression you raise that heat to a level high enough so that you can reject it in most cases to the atmosphere in the pantry or kitchen or basement or wherever it is.

The heat pump is exactly the same thing; that is all it is. Its heat cycle takes the heat from any source where you have heat--from the air, from water, or from the well if you have one--it will take it from your drinking water if you so choose. If you have a pond in back of your house, you can use the pond as a source of heat. You pick up that heat through an evaporator; it can be at a relatively low level, say, at 32 F or at 10 F. That is quite all right. By compression you raise it high enough to bring it to a sensible level. A sensible level of temperature for the average house would be something near 80, 90, or 100 degrees. You can even heat water if you raise the temperature higher.

Obviously, if you have that same equipment available for heating, you can just reverse the cycle and by reversing your evaporator so that it becomes the condenser in the circuit, you can use the equipment for cooling. The heat pump is merely a compressor circuit having a compressor, an evaporator, a condenser, and a fan, which utilizes these to air-condition your home. You can heat or cool it. You can switch from one to the other as fast as your control circuit indicates that you ought to do it.

The basic idea is not new; it was first suggested by Lord Kelvin. The details and some of the things we have worked out in the last half-dozen years are new, but these were all engineering details.

Actually, the way to look at this heat pump is that a heat pump is a source of fuel. That is, you have an awful lot of fuel just outside this building, for example, in the surrounding air. Perhaps, at certain seasons, it is at a relatively low temperature, but it is still the equivalent of millions of tons of coal or oil. By proper utilization of the heat pump, that heat can be made available for useful purposes. The heat pump can also be used to carry on a cooling process by doing the reverse and rejecting the heat.

You might be interested in this: We have some 10 office buildings in our system heated and cooled by heat pumps. We also have today about 25 residences similarly serviced. And we have at this time a half-dozen hot water heaters that provide hot water by the heat pump. These utilize stray heat in the kitchen or bathroom, raising the temperature of this heat so that we deliver a 145 F flow of water. The hot water heater cools the atmosphere and gives you hot water at the same time.

COLONEL VAN WAY: I think on that encouraging note for the future we should close this session. Mr. Sporn, we are truly indebted to you for the generous use of your time in coming down here and giving us so many fascinating facts. We are particularly grateful that you made it so interesting and so understandable. Thank you very much.

(24 July 1951--650)S.

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TABLE 1

GROSS NATIONAL PRODUCT AND ELECTRIC POWER PRODUCTION
UNITED STATES
1929 - 1950

YEAR	GROSS NATIONAL PRODUCT (Billions of Dollars)		ELECTRIC GENERATION, PUBLIC UTILITIES (Billions of KWH)	
	Actual	Index 1929/100	Actual	Index 1929/100
1929	103.8	100.0	92.2	100.0
1930	90.9	87.6	91.1	98.8
1931	75.9	73.1	87.4	94.8
1932	58.3	56.2	79.4	86.1
1933	55.8	53.8	81.7	88.6
1934	64.9	62.5	87.3	94.7
1935	72.2	69.6	95.3	103.4
1936	82.5	79.5	109.3	118.5
1937	90.2	86.9	118.9	129.0
1938	84.7	81.6	113.8	123.4
1939	91.3	88.0	127.6	138.4
1940	101.4	97.7	141.8	153.8
1941	126.4	121.8	164.8	178.7
1942	161.6	155.7	186.0	201.7
1943	194.3	187.2	217.8	236.2
1944	213.7	205.9	228.2	247.5
1945	215.2	207.3	222.5	241.3
1946	211.1	203.4	223.2	242.1
1947	233.3	224.8	255.7	277.3
1948	259.1	249.6	282.7	306.6
1949	255.6	246.2	291.0	315.6
1950	279.8*	269.6	329.0*	356.8

* Preliminary

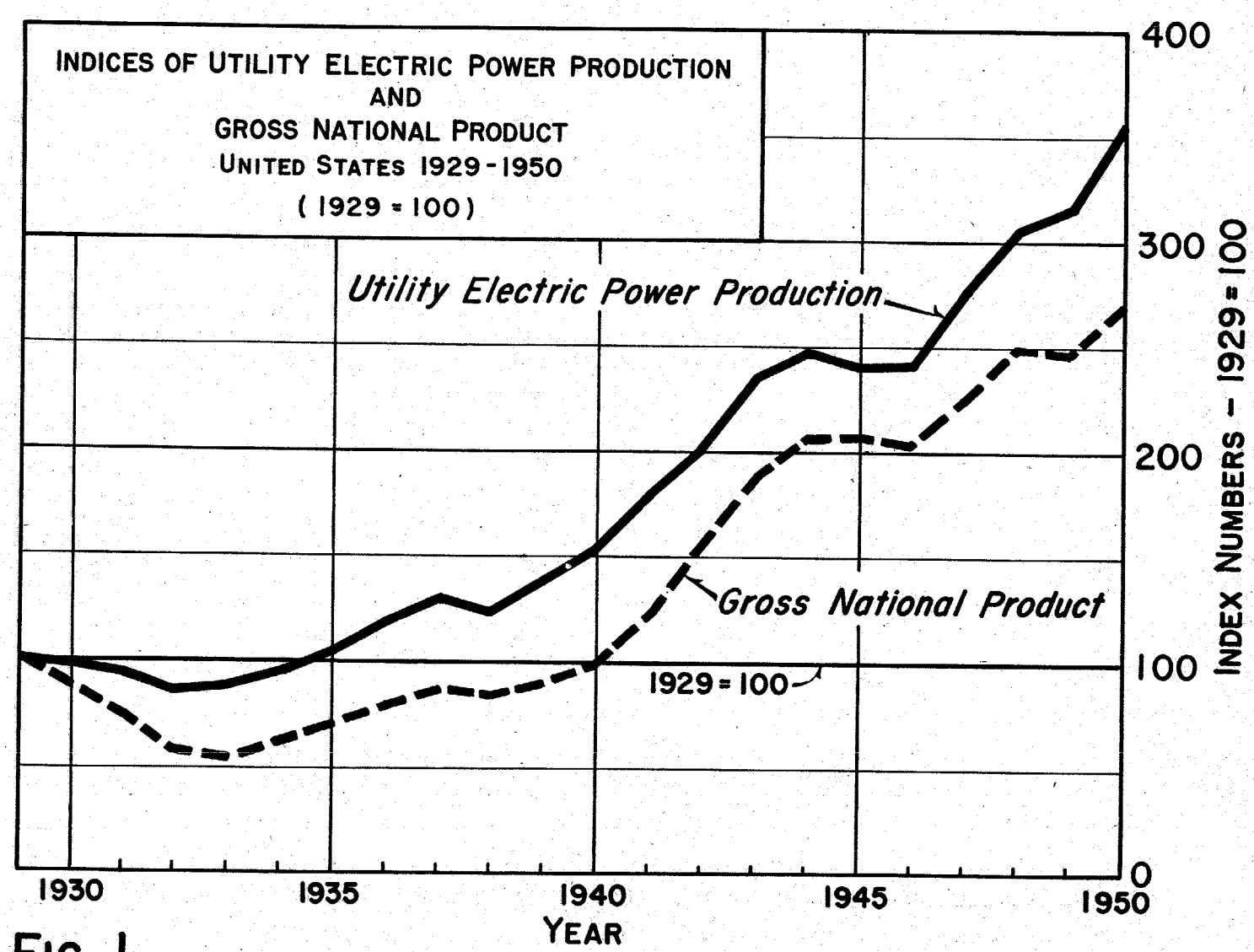

FIG. 1

April, 1951

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TABLE 2

COST AND CONSUMPTION OF ELECTRIC ENERGY IN TWENTY MAJOR INDUSTRY GROUPS IN THE UNITED STATES

1947

INDUSTRY	STANDARD INDUSTRIAL CLASSIFICATION No.	ELECTRIC ENERGY					VALUE OF PRODUCTS SHIPPED ($000)	PURCHASED ELECTRIC ENERGY - PERCENT OF VALUE OF PRODUCTS SHIPPED [3]
		Generated (Kwh x 10^6)	Purchased (Kwh x 10^6)	Sold (Kwh x 10^6)	Consumed (Kwh x 10^6)	COST OF PURCHASED ELECTRIC ENERGY ($000)		
All Industries, Total		43,936	102,822	5,811	140,947	954,717	166,821,266	0.782
Food and Kindred Products	20	1,838	8,427	85	10,180	108,531	31,958,377	0.41
Tobacco Manufactures	21	76	155	12	219	2,174	2,541,241	0.12
Textile Mill Products	22	1,959	8,288	206	10,041	82,456	10,980,608	0.91
Apparel and Related Products	23	18	837	5	850	20,567	10,383,274	0.20
Lumber and Products (Exc. Furniture)	24	1,004	1,503	169	2,338	19,964	4,691,931	0.66
Furniture and Fixtures	25	128	705	7	826	11,670	2,640,976	0.52
Paper and Allied Products	26	9,626	6,175	415	15,386	50,606	7,051,485	1.79
Printing and Publishing	27	39	1,251	10	1,280	23,796	6,354,901	0.38
Chemicals and Allied Products	28	8,058	11,963	411	19,610	85,405	11,885,479	1.17
Petroleum and Coal Products	29	3,246	3,753	501	6,498	28,293	8,276,272	0.59
Rubber Products	30	810	2,650	15	3,445	24,685	2,716,447	1.18
Leather and Leather Products	31	117	475	19	573	8,888	3,673,849	0.29
Stone, Clay and Glass Products	32	2,155	5,865	122	7,898	54,878	3,633,599	2.04
Primary Metal Industries	33	11,851	31,428	2,634	40,645	188,784	16,600,000 [2]	1.47
Fabricated Metal Products	34	170	3,739	8	3,901	53,957	9,152,925	0.61
Machinery (Exc. Electrical)	35	579	5,401	59	5,921	71,952	13,554,517 [1]	0.58
Electrical Machinery	36	574	3,156	114	3,616	34,578	6,221,765 [1]	0.63
Transportation Equipment	37	1,497	5,552	988	6,061	59,242	8,944,031 [1]	0.73
Instruments and Related Products	38	90	456	1	545	6,763	1,853,017	0.43
Miscellaneous Manufactures	39	101	1,043	30	1,114	17,528	3,706,572	0.51

NOTES: [1] Partially estimated, but estimates form a relatively small part of the total.

[2] Steel ingots, primary copper shipments, etc. not given. Total is largely estimated.

[3] In determining the % Cost of Purchased Power to Value of Product, the value of product assignable to purchased power was obtained by pro-rating the total value of product on the basis of the ratio of purchased power to the net private plant generated power.

SOURCE: 1947 Census of Manufactures.

TABLE 3

COST AND CONSUMPTION OF ELECTRIC ENERGY IN VARIOUS SPECIAL INDUSTRIES IN THE UNITED STATES

1947

INDUSTRY	STANDARD INDUSTRIAL CLASSIFICATION No.	ELECTRIC ENERGY					VALUE OF PRODUCTS SHIPPED ($000)	PURCHASED ELECTRIC ENERGY - PERCENT OF VALUE OF PRODUCTS SHIPPED [2]
		Generated (Kwh x 10^6)	Purchased (Kwh x 10^6)	Sold (Kwh x 10^6)	Consumed (Kwh x 10^6)	COST OF PURCHASED ELECTRIC ENERGY ($000)		
Pulp, Paper, Paper Board	261	9,431	5,411	413	14,429	39,660	3,751,652	2.81
Industrial Inorganic Chemicals	281	3,111	4,541	65	7,587	23,498	881,205	4.47
Alkalies and Chlorine	2812	1,900	1,111	47	2,964	5,635	208,560	7.27
Cement, Hydraulic	3241	2,364	1,866	106	4,230	17,021	408,928	9.42
Electrometallurgical Products (Steel)	3313	1,282	3,621	-	4,803	13,519	150,904	11.71
Primary Nonferrous Metals	333	1,410	11,329	85	12,654	32,302	1,014,188 [1]	3.61
Copper	3331	328	492	-	820	3,015	340,000 [1]	1.47
Lead	3332	8	133	-	141	981	300,000 [1]	0.35
Zinc	3333	(1,074	1,341	3	(11,743	6,102	190,996 [1]	(
Aluminum	3334	(	9,331	-	(	21,910	161,010	(12.27
Other Nonferrous	3339	-	32	-	32	294	22,182	1.32

NOTE: [1] Estimate.

[2] In determining the % cost of Purchased Power to Value of Product, the value of product assignable to purchased power was obtained by pro-rating the total value of product on the basis of the ratio of purchased power to the net private plant generated power.

SOURCE: 1947 Census of Manufactures.

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TABLE 4

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

1949

Country	Population [1] (000's)	Kwh Produced (000,000's)	Kwh/Capita
Argentina	16,600 (Est.)	3,313	200
Belgium	8,614	8,163	948
Brazil	49,340	2,710	55
Canada	13,549	50,647 [6]	3,738
Chile	5,709	1,283	225
China	465,000 (Est.)	1,879 [4]	4
France	41,550	28,404	684
Germany (Bizone)	47,585	35,723	751
Greece	7,856	382 [3]	49
Israel	1,100 (Est.)	329	299
Italy	45,996	22,334 [6]	485
India	346,000	4,922	14
Mexico	24,448	4,326	177
Norway	3,233	15,183	4,696
Pakistan	74,400	162	2
Spain	28,023	5,044	180
Sweden	6,956	16,104	2,315
Switzerland	4,640	7,767	1,674
Turkey	19,623	682	35
United Kingdom	50,363	52,204	1,037
United States	149,215	344,537 [6]	2,309
U.S.S.R.	210,000 (Est.)	74,000 [2]	352
Yugoslavia	16,040	1,800 [5]	112

NOTES: [1] Mid-year population.

[2] Based on Indices of Production

[3] 1947

[4] 1948

[5] 1944

[6] Includes Industrial Production

SOURCES: United Nations, Monthly Statistical Bulletin; EEI Estimates.

TABLE 5

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[4]	52	17,154	48
1925	53,095	29,880[4]	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[3]	193,065[3]	77	58,926[3]	23

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

[2] Large Light and Power.

[3] Preliminary.

[4] Estimated.

SOURCES: EEI; Historical Statistics of the United States.

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TABLE 6

TOTAL U.S. ELECTRIC GENERATING CAPACITY AND ELECTRIC GENERATION

(Including Industrial Generation)

Year	Installed Capacity			Total Generation (Thousands of kwh)
	Public Utilities	Other	Total	
1935	34,435,768	7,710,000 *	42,146,000	118,935,000
1936	35,081,569	8,500,000	43,581,569	136,006,000
1937	35,620,011	8,750,000	44,370,011	146,476,000
1938	37,492,095	9,381,000	46,873,095	141,955,000
1939	38,862,716	10,575,449	49,438,165	161,309,000
1940	39,926,881	11,035,462	50,962,343	179,937,000
1941	42,405,436	11,589,809	53,995,245	208,307,000
1942	45,052,950	12,184,237	57,237,187	233,179,000
1943	47,950,767	12,588,603	60,539,370	267,540,000
1944	49,189,072	12,876,664	62,065,736	279,525,000
1945	50,110,928	12,756,886	62,867,814	271,255,000
1946	50,316,621	12,693,586	63,010,207	269,362,000
1947	52,322,007	12,767,759	65,089,766	307,310,000
1948	56,559,838	13,054,872	69,614,710	336,808,000
1949	63,100,334	13,469,738	76,570,072	345,066,000
1950	68,500,846	13,911,972 **	82,412,818 **	387,924,000 **

NOTES: * Estimated by Federal Power Commission.

** Preliminary.

SOURCE: EEI

TABLE 7

GROWTH OF POWER USE IN THE UNITED STATES 2151

1935 - 1950

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 *

NOTE: * Preliminary.

SOURCE: EEI

TABLE 8

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

1939-1950

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

Source: EEI

TABLE 9

TOTAL STEAM AND HYDRO ELECTRIC GENERATING CAPACITY SCHEDULED FOR INSTALLATION ON PUBLIC SUPPLY SYSTEMS OF THE UNITED STATES 1951 - 1954[1]

(Units of 4,000 kw and larger)

Year	Electric Utilities [2]		
	Total Capacity	Steam	Hydro
1951	6,570,600	5,288,000	1,282,600
1952	10,367,100	8,560,000	1,807,100
1953	8,987,700	8,113,500	874,200
1954	1,781,000	1,208,500	572,500
Total	27,706,400	23,170,000	4,536,400

[1] Preliminary Data as of April 1, 1951, from Edison Electric Institute 9th Semi-Annual Power Survey.

[2] Includes both publicly and privately owned utilities.

TABLE 10

ESTIMATED PEAK LOADS, CAPABILITIES AND RESERVE MARGINS [1] IN THE UNITED STATES

1951 - 1954

I Median Hydro Conditions

Year	Peak Load (000 kw)	Capability (000 kw)	Reserve Margins	
			(000 kw)	(% of Peak)
1951	68,664	74,351	5,687	8.3
1952	75,278	84,038	8,760	11.6
1953	81,473	94,473	12,979	15.9
1954	86,817	100,472	13,655	15.7

II Adverse Hydro Conditions

Year	Peak Load (000 kw)	Capability (000 kw)	Reserve Margins	
			(000 kw)	(% of Peak)
1951	68,618	72,989	4,371	6.4
1952	75,232	82,112	6,880	9.1
1953	81,448	92,452	11,004	13.5
1954	86,771	98,457	11,686	13.5

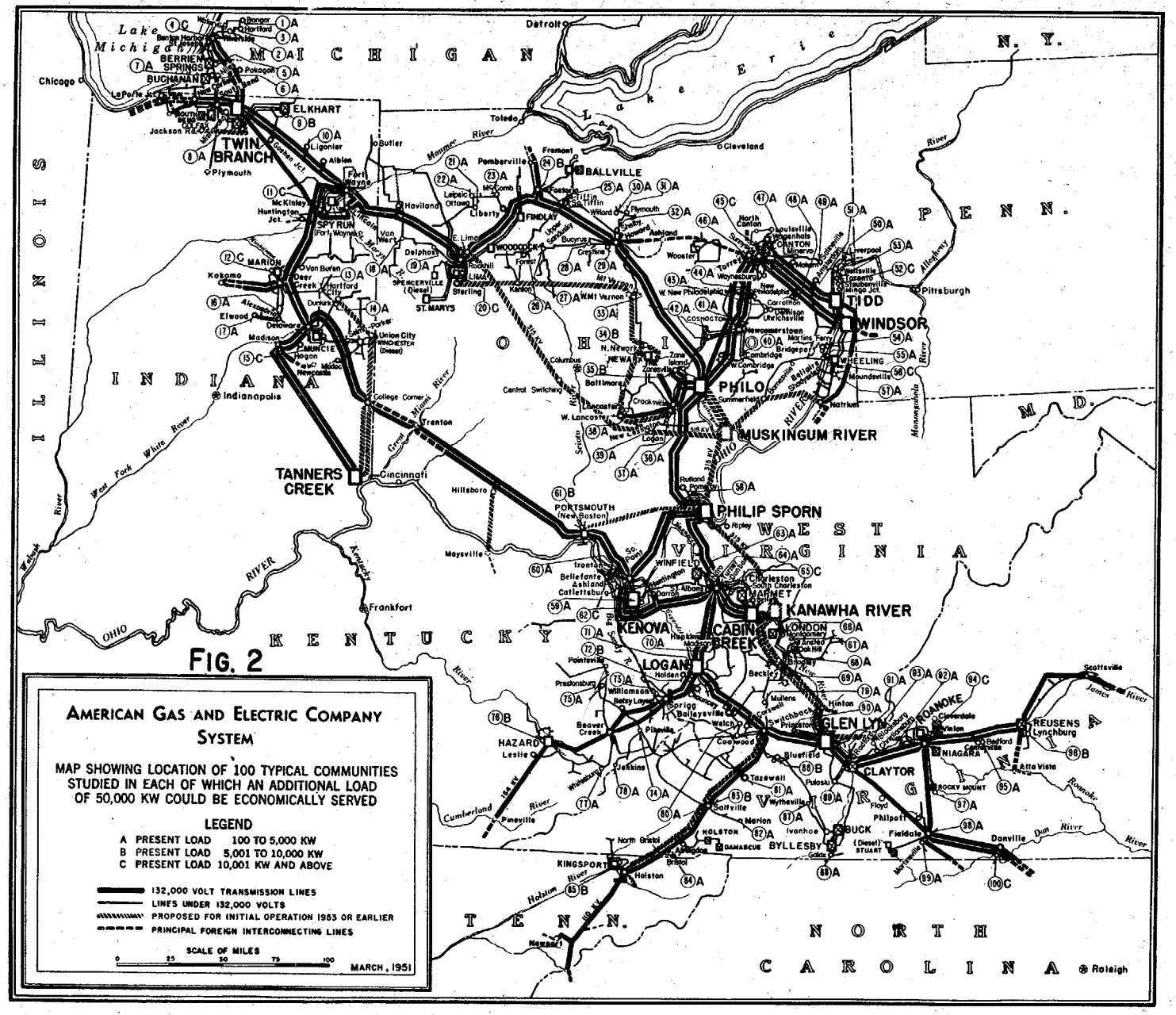
[1] Preliminary Data as of April 1, 1951, from Edison Electric Institute 9th Semi-annual Power Survey.

TABLE 11

INCREASE IN GENERATION OF PUBLIC SUPPLY SYSTEMS AND LOAD FACTORS IN THE UNITED STATES

1939 - 1950

Year	Increase Over Preceding Year				Annual Load Factors - %	
	Peak Demand (Thousands of Kwh)	% Change	Generation (Thousands of Kwh)	% Change	Load Factor on Increased Demand	System Load Factor
1939	3,350	+ 13.2	13,829,433	+ 12.2	47.1	50.8
1940	2,100	+ 7.3	14,195,206	+ 11.1	77.2	52.6
1941	3,850	+ 12.5	22,950,868	+ 16.2	68.1	54.3
1942	1,200	+ 3.5	21,191,598	+ 12.9	201.6	59.4
1943	4,250	+ 11.9	31,779,355	+ 17.1	85.4	62.0
1944	550	+ 1.4	10,430,013	+ 4.8	216.5	64.2
1945						64.2
1946						56.6
1947						58.9
1948						60.0
1949						58.8
1950						58.6


AMERICAN GAS AND ELECTRIC COMPANY SYSTEM
MAP SHOWING LOCATION OF 100 TYPICAL COMMUNITIES STUDIED IN EACH OF WHICH AN ADDITIONAL LOAD OF 50,000 KW COULD BE ECONOMICALLY SERVED
LEGEND
A PRESENT LOAD 100 TO 5,000 KW
B PRESENT LOAD 5,001 TO 10,000 KW
C PRESENT LOAD 10,001 KW AND ABOVE
132,000 VOLT TRANSMISSION LINES
LINES UNDER 132,000 VOLTS
PROPOSED FOR INITIAL OPERATION 1953 OR EARLIER
PRINCIPAL FOREIGN INTERCONNECTING LINES
SCALE OF MILES
0 25 50 75 100
MARCH, 1951
MICHIGAN
INDIANA
ILLINOIS
OHIO
PENN.
N. Y.
MD.
WEST VIRGINIA
KENTUCKY
TENN.
NORTH CAROLINA
Lake Michigan
Lake Erie
TWIN BRANCH
ELKHART
SPY RUN
MARION
MUNCIE
TANNERS CREEK
BALLVILLE
TIDD
WINDSOR
PHILO
MUSKINGUM RIVER
PHILIP SPORN
KENOVA
CABIN CREEK
KANAWHA RIVER
LOGAN
HAZARD
GLEN LYN
CLAYTOR
ROANOKE
NIAGARA
REUSENS
BUCK
BYLLESBY
KINGSPORT
Chicago
Detroit
Toledo
Cleveland
Pittsburgh
Indianapolis
Cincinnati
Frankfort
Raleigh
Lynchburg
Danville
Scottsville
Roanoke River
Kanawha River
Ohio River
Cumberland River
Tennessee River
Holston River
Dan River
James River
Kentucky River
Wabash River
West Fork White River
Great Miami River
Maumee River
Muskingum River
Monongahela River
Allegheny River
Scioto River
Big Sandy River
Licking River
Hocking River
Guyandotte River
Tug Fork
Levisa Fork
Pine Creek
Beaver Creek
Pike Creek
Big Creek
Paint Creek
Elk River
Kanawha River
Gauley River
New River
Greenbrier River
Bluestone River
Clinch River
Powell River
Holston River
Nolichucky River
Pigeon River
Little Pigeon River
Tuckasegee River
Nantahala River
Hiwassee River
Ocoee River
Little River
Tellico River
Little Tennessee River
Pine River
Leslie
Pineville
Beaver Creek
Williamson
Pikeville
Jenkins
Whitesburg
Hindman
Paintsville
Prestonsburg
Pointsville
Catlettsburg
Ashland
Bellefonte
Ironton
Portsmouth (New Boston)
Maysville
Hillsboro
Cincinnati
Trenton
College Corner
Union City
Winchester (Diesel)
Madison
Hogan
Newcastle
Kokomo
Elwood
Alexandria
Anderson
Muncie
Deer Creek
Van Buren
Hartford City
Dunkirk
Delphos
Van Wert
Spencerville (Diesel)
St. Marys
Sterling
Lima
Rockhill
Wooddale
Forest
Kenton
Findlay
Upper Sandusky
Buyrus
Crestline
Mt. Vernon
Fremont
Pemberville
Lepsic
Ottawa
Liberty
Mc Comb
Fostoria
Tiffin
Willard
Plymouth
Shelby
Ashland
Wooster
Canton
Massillon
Alliance
Louisville
Wagenhals
Minerva
Mineral
Salineville
Wellsville
Toronto
Steubenville
Mingo Jct.
Liverpool
Carrollton
Uhrichsville
Newcomerstown
Martins Ferry
Bridgeport
Wheeling
Moundsville
Natrium
Bellaire
Shadyside
Powhatan
Somerville
Cambridge
W. Cambridge
Zanesville
Zane Island
Crooksville
Summerfield
Rutland
Pomeroy
Logan
New Lexington
W. Lancaster
Lancaster
Baltimore
Newark
N. Newark
Columbus
Central Switching
Winfield
Charleston
South Charleston
Marmet
Kanawha
Montgomery
London
Oak Hill
Beckley
Mullens
Hinton
Switchback
Princeton
Bluefield
Tazewell
Pulaski
Wytheville
Saltville
Marion
Ivanhoe
Galax
Stuart
Floyd
Philpott
Fieldale
Rocky Mount
Roanoke
Clearwater
Vinton
Bedford
Campbell
Altavista
Scottsville
Lynchburg
Danville
Bristol
Holston
Kolston
Damascus
Pineville
Newport
Cumberland
Hazard
Leslie
Beaver Creek
Williamson
Pikeville
Jenkins
Whitesburg
Hindman
Paintsville
Prestonsburg
Pointsville
Catlettsburg
Ashland
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Shelby
Ashland
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Tazewell
Pulaski
Wytheville
Saltville
Marion
Ivanhoe
Galax
Stuart
Floyd
Philpott
Fieldale
Rocky Mount
Roanoke
Clearwater
Vinton
Bedford
Campbell
Altavista
Scottsville
Lynchburg
Danville
Bristol
Holston
Kolston
Damascus
Pineville
Newport
Cumberland
Hazard
Leslie

FIG. 2

C 8092