ENERGY RESOURCES

10 October 1950

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COLONEL WATERMAN: Gentlemen, in his introductory lecture on "Natural Resources," Colonel Hickey enumerated three distinct categories of resources--minerals, energy resources, and agricultural products. We have already had a discussion on one category of the minerals group, ferrous materials. This morning we delve into the second category, "Energy Resources."

Our speaker this morning is Commander E. W. Davis of the Civilian-Reserve Instruction Branch.

COMMANDER DAVIS: You know, you hear these speakers who come up here and listen to their introductions then they get up and invariably say that they had a hard time recognizing who was being talked about. I didn't have any trouble recognizing who he was talking about.

The thing that distinguishes the human being from all other living creatures is supposedly his ability to reason. And the thing that distinguishes the civilized human being from his primitive brother is his ability to apply sources of energy to productive ends. The face of the progress of civilization has been governed almost directly by the proportion of energy that human beings have been able to harness to their needs. The industrial leadership of the United States today is a direct outgrowth of our adaptation, to the industrial process, of our great energy resources.

Water power, coal, gas, and oil are the principal sources from which we fill our requirements for energy. What we must do toward the conservation of those resources, toward insuring their orderly development and toward guaranteeing their readiness for use in case of national emergency, are matters of vital national concern. And of no less importance is the future economic health of those industries that serve to convert those energy resources into usable form.

This morning we are going to discuss the roles of water power, electric power, atomic power, manufactured and natural gas in our economy, both in peace and in war. I have excluded petroleum because that subject will be given in a later lecture. Now although each of these energy resources will be discussed separately, it must be recognized that each of these resources complements, competes with, and affects each of the others.

But before getting into these separate discussions, I have first a chart which shows the changing pattern of usage of our energy resources. It is interesting to notice the increase in the use of mineral fuels, principally at the expense of coal. Today the energy provided by gas and petroleum equals that provided by coal, both at 48 percent.

Well, for the first of our discussions, let us start with water power. About one-third of the electric energy generated in the United States has its origin in water power, and, as you can see, water power supplies a very important fourth of our energy requirements. Water power is a unique source of energy. While our resources of coal, oil, and gas are limited and cannot be replenished, the supply of water power is not reduced by use and it is actually wasted if it is not used. It is this characteristic, together with the fact that the production of power is only one of the uses to which water is put, that gives it a special publi interest.

Dams and other power-generating structures will affect the other uses of water and of the stream, and therefore power must be considered with respect to these other uses, and, conversely, these other uses must be considered with respect to power. It is in these "other uses" for dams and power-generating structures that we find the basis for the current issue concerning the relative merits of Federal Government versus private development of power. This issue is of such current and continuing importance that I feel it warrants a review of some of the background.

The huge and spectacular hydroelectric projects which were started b the Government in the early thirties may have appeared to have been a New Deal creation. Actually, the stage was set for the current controve by the Reclamation Act of 1902. This act was designed to provide irrigation on a vast scale for the semiarid regions of the West. The da which were built to impound the irrigation water could be used to produc power, which was useful, of course. It could be used to pump the water into the irrigation systems and its sale could help offset the cost of t dam. At these early stages, however, there was no question as to the primary purpose of these projects. It was irrigation, pure and simple. In the ensuing years many more government projects were legislated, but with practically no variation, they were legislated for one of three primary reasons--irrigation, flood control, or navigation, with power production definitely secondary. (Chart was not reproduced.)

But the day was bound to come when the amount of government-generated power would be a substantial percentage of the total, and an issue would arise. And that day came with the creation of Boulder, Bonneville, Grand Coulee, and Fort Peck Dams and the Tennessee Valley Authority. The private power interests are putting up a strong fight

in the field of power against this government expansion. It is interesting to note that in at least one section of the country, the Pacific Northwest, these private interests have finally conceded that from now on it will be up to the Government to construct these huge projects, but they insist on the right to retain the distribution privileges, in other words to buy power from the Government and to distribute it to the eventual consumer.

The major arguments against government control of power are that the Government is competing unfairly with private business, in that the Government does not pay taxes, that a large part of the original cost is written off for irrigation, flood control, and navigation, and that it is the first step toward socialism.

The proponents of government power say that only the Government has the capital necessary to build these huge projects and that the government power results in lower real rates to the consumer and that the private power interests invariably underestimate the huge demands for power which the country needs.

Now just to orient our thoughts as to the magnitude of this issue, government-owned plants today account for about one-fifth of the total United States generating capacity. The feasible undeveloped water-power sites in the United States are estimated to be capable of producing approximately four times the amount produced from water today. If all these feasible sites were developed, they would furnish about 20 percent of our total energy requirements. However, today about half of these so-called feasible sites are not economically justifiable.

The water-power projects now authorized or under way will have a generating capacity equal to about double the existing hydroelectric capacity. One important point to bear in mind in connection with hydroelectric projects is that--this is particularly true in wartime--a hydroelectric plant requires a considerably longer time to construct than a plant powered by oil or coal. It would be very costly in men and materials to attempt to start a hydroelectric project after the beginning of a war.

Now we come to the over-all field of electric power. Electric power in its relation to our national security is a subject of vital importance to all Americans, particularly to those concerned with national security, especially when you consider that with less than one-sixteenth of the world's population we produce 40 percent of the world's electric power.

National security planning for electric power is primarily concerned with two things--the creation of an adequate reserve of generating capacity, particularly in the chief munitions production centers; and the construction of a system of interconnections, linking power sources with load centers.

First, reserve capacity.--We have three kinds of reserve generating capacity. There is, first, the excess capacity that is built into a plant at the time of its construction to take care of anticipated future requirements. Second, there are the "spinning reserves" which are represented by generators on the line, not carrying a load, but which are available for use in case of surges in power demand. And third, there are the maintenance reserves, which are the extra generators provided as stand-by's for disabled units or for those requiring repair or overhaul.

We were fortunate at the start of World War II in having an excess of reserve capacity to meet the expanding needs of war industry, but ever so, loads increased so rapidly that many old and relatively inefficient plants had to be pressed into use. We were also fortunate that the huge hydroelectric projects at Grand Coulee, Bonneville, and the TVA were all nearing completion. Yet the demands for additional power could not be met without the construction of additional plants. Certainly new construction must be expected if we become engaged in another war.

During and after World War II the electric-power reserve capacity dropped from 26 percent at the start of the war to 1.5 percent in 1948. This continued demand for increasing amounts of electric power came as a complete surprise to both government and private power interests. Plants in some areas were required to operate as high as 105 percent of reserve capacity.

The amount of reserve capacity needed in any particular area can be reduced by better "round the clock" use of electric power, by controlling abrupt changes in demand, and by power-pooling arrangements through interconnections with other systems. Interconnections with two or more systems make the reserve capacity of one available to each of the others, and since different systems have different load characteristics, and these depend on the type of industry served, time zones, domestic usages, and other factors, it is generally feasible and desirable to interconnect these power systems and so save different installations and additional power-generating equipment to meet these peak demands. Obviously, power pooling in the event of war damage to generating plants has definite advantages.

Let me give an example of what I mean by interconnection. Take Washington, D. C., a nonindustrial area--we have a normal load of 450,000 kw., and we have interconnections to the north which are good for

100,000 kw., and to the south for about 15,000 kw. There are here in the District two local generating plants, one of 300,000 kw. capacity, and the second is half that size.

If either of these major plants were destroyed by wartime action, the only means of supplying Washington's power needs would be through more effective use of interconnections, pending repair and replacement of the damaged plant.

Of course, we should not forget one pertinent fundamental point in discussing this problem of wartime disruption of power through enemy action. It is quite possible in a widespread area bombing that not only the power plant would be lost, but the consumer load would be lost also. However, there does remain the very definite possibility of sabotage, and some planning should be done to cover this very definite wartime hazard.

It is considered doubtful that 100 percent interconnection would ever be feasible, but it would certainly be well to have the engineering planning accomplished to cover any type of emergency. We find a reluctance on the part of some private power interests who are engaged in intrastate business to interconnect with companies that are engaging in interstate business for fear of incurring dual control between state and Federal regulatory bodies.

My next chart gives the past, present, and forecast status, showing the peak capacity and the load, with the reserve margin shown as a percentage of the peak load. This chart shows the conditions for the years 1949 through 1952 under two sets of conditions, the adverse or poor water conditions and the median or average conditions, the difference between the two being felt in the reserve margins. (Chart was not reproduced.)

I have previously mentioned that at the start of World War II we had a reserve capacity of 26 percent. Today our power requirements are above the peak demands of the war and the demand curve is still rising. In 1948 we used nearly twice as much electric power as we did in 1940. Our reserve capacity today is in the nature of 9 to 11 percent. However, there is a six billion dollar building program under way, and by 1951 we will have increased our kilowatt capacity by more than 40 percent. There are few industries that can equal that record of postwar expansion. Also, this is the only major industry which charges less for its product than it did before the war. By 1952, or possibly earlier, we can expect a reserve capacity of 15 percent, which is the marginal value considered adequate by planners in the National Security Resources Board.

The NSRB, in cooperation with private industry, has undertaken a complete and continuing survey of our electric-power resources. They have two committees in operation--one to study the capacity and the requirements of power generating systems, and the other to study the status and production of heavy generating equipment. The reports of these two NSRB committees form the basis on which economic mobilization plans for our power-generating plants, their distribution systems, and their supporting industries are being formulated.

One can well imagine that if wartime controls are ever again instituted, one of the first to be considered will be the rationing of both industrial and residential power. Brown-outs and black-outs may be dictated as much by economic mobilization considerations as by military considerations. Certainly the onset of another war would bring demands for electric power far beyond that which would result from the normal growth of our country. Planners for the future must give consideration to the fact that, while most new war plants require from two to four months to build, new power plants require from 18 to 24 months. So much for electric power.

Now in connection with the field of power, I am going to have a little to say about our Nation's most recent and dramatic power source, atomic power. The key fact about the development of power from atomic energy sources is that no one in the United States needs atomic power very badly. What we could have, in the not too very distant future, is practically unlimited source of electric energy from atomic power. But with out coal resources good for at least a thousand years and with abundant water power, that idea isn't very exciting. So it is these economic factors rather than the technical ones which will determine the "how soon" of atomic power.

The Atomic Energy Commission has two rather extensive contracts for its power development work and their plans call for a commercially feasible plant about 1960. But in Europe, with its already developed industry and its scarcity of fuels, they are not apt to be so casual about power from atomic sources. It is considered entirely possible that we may see the development of atomic powered generating plants outside the United States.

Our scientists seem to agree that the application of atomic power on a basis of small units shows promise as a means of meeting the needs of both large and small industrial users at costs below those of usual power systems. The small bulk of nuclear fuels should certainly favor this type of operation as it would greatly reduce the problems of fuel transportation and storage.

The technical problems which, as I have stated, are by no means insurmountable, center on the matter of heat transfer--how to convert

heat generated by controlled atomic explosion into usable form. Obviously, that one isn't easy when you consider the radiation activity involved. Of course, there remains what has been called the "Great White Hope" that some scientist some day will happen across a way of converting nuclear energy directly into electric energy. Even that idea, while remote, remains a possibility.

The Atomic Energy Commission is beginning to spend 90 million dollars on the design and construction of four new atomic piles, none of them concerned with the manufacture of bombs. One of them will explore the theory of breeding, that is, the transformation of nonfissionable material into fissionable materials under neutron bombardment. Another is going to be used to determine the possibilities of ship propulsion. A third will attempt to determine the general reaction of all materials under nuclear bombardment. The fourth will be constructed to generate power. A contract of about 40 million dollars has been let to the General Electric Company which is engaged in the construction of a reactor at Schenectady, New York.

The General Advisory Committee of the AEC, composed of such people as Conant and Oppenheimer, has said that it is unlikely that any considerable part of the world's power supply will come from atomic power in the next 20 years. Recently, however, this new AEC reactor program has caused certain scientists to speak of these possibilities with what they term "cautious enthusiasm."

Now we get into the matter of fuels. Virtually every extractive, manufacturing, and distributive process in our economy depends on the consumption of mineral fuels. Coal and petroleum, plus iron, form the bedrock of military power. Steel is a sinew of war and coal is essential in the manufacture of steel. It takes about one ton of coal to make the coke needed to smelt one ton of iron from the ore. Then additional quantities of coal are needed to convert the iron into steel and the steel into fabricated products. Electric-power generation uses about one-sixth of our coal production; another sixth goes to our railroads; another sixth to the steel industry; one-third for all other industry; and most of the remaining sixth for retail deliveries such as home heating. Of all the industries, power generation is the greatest single user of coal.

Coal reserves in the United States and Canada represent nearly 60 percent of the world's total and are estimated to be sufficient to meet the needs of the entire Western Hemisphere for at least a thousand years. The better quality reserves are not so plentiful, but blending will insure an adequate supply of those better quality coals for several hundred years. With such huge reserves of coal in the United States, we will ultimately have to make better use of them.

The coal companies in conjunction with the Bureau of Mines have been doing a great deal of research in the past in new and better uses for coal. One of the more interesting studies is that in connection with the locomotive steam turbine, a program by which it is hoped to achieve a coal burning steam turbine locomotive. A full-scale test is now going on and they report real progress.

In this locomotive, fine powdered bituminous coal is used. Such a development would be of great assistance to the railroads, particularly in the East where coal is abundant and constitutes such an important item of their freight. Such a development could slow down the trend to the complete dieselization of the railroads and might even result in the ultimate return to the use of coal.

During 1949, strikes, warm weather, high prices, and all the other ailments of the coal industry resulted in a decrease in the production of soft coal--down 29 percent, from 600 million tons in 1948 to 430 million. Anthracite production was lower than it was in any year since 1902.

The productive capacity of the coal industry is completely adequate to meet any of our demands, but there are several factors that prevent us from viewing the coal situation with complacency. Usual procedures in the industry result in our having a 30-to 40-day supply of coal above ground. Any serious disruption to either the transportation process or to the mining process could, and, as you well know, does, result in tight situations. Also in wartime we can count on many liquid-fuel consuming units converting back to coal, all of which would require more mining activity and more transportation activity, both thereby needing more manpower, not to mention more coal cars for the railroads. Both manpower and coal cars are going to be hard to furnish in a war economy.

The next fuel to consider is gas, manufactured and natural. Manufactured gas is produced as a primary or by-product of processes utilizing either coal or oil. Coke oven gas accounts for about 75 percent of all manufactured gas, with the public gas utility system consuming about one-third and the balance going to industrial uses. Manufactured gas product is going to increase in wartime along with the increase of coke productio for steel.

Natural gas ranked third in 1949 as an energy source, providing about 12 percent of all our energy consumed. At present the use of natural gas is increasing just as fast as pipelines can be built. Over 7,000 miles of pipelines were placed in operation in 1948; 15,000 miles, last year; and today our total gas pipeline mileage, including both well-gathering systems and the distribution lines, totals 251,000 miles which, incidentally, is greater than the line mileage of all our railroads.

The gas is produced primarily in the Southwest, either from fields which are strictly gas producing or from processes in conjunction with petroleum. The known reserves of natural gas are estimated to be adequate for at least 40 years and they are constantly increasing with new discoveries. Consumption doubled between 1923 and 1935, doubled again in the next ten years, and the experts believe that it will double again in the coming decade. Much of that increase results from gas supplanting coal as a fuel.

Natural gas is used extensively in the glass, ceramics, and cement industries. There is a tremendous demand for natural gas as a chemical industry base stock for making dyes and drugs--one example is novocain. Natural gas is also used for synthetic rubber, paint solvents, and antifreeze.

There is today a commercial plant just about ready to be put into operation in Brownsville, Texas. It will produce--from natural gas--6,000 barrels a day of gasoline, 900 barrels a day of fuel oil, and 300,000 pounds of chemicals.

There you have in very broad outline the power and fuel situation of the United States, omitting petroleum. Now let us draw some conclusions.

The pattern of our sources of energy is changing constantly, with petroleum and natural gas supplying more and more of our needs. Water-power resources are being developed by both private interests and by the Government at a reasonably satisfactory rate. Electric power is emerging from a very tight situation and it is expected that reserves will be adequate in the near future. Atomic power is feasible but its development awaits an economic need. Coal reserves are generally ample; only the special coals are becoming tighter, and labor problems within the industry continue to be difficult.

Kilowatts of electric power, tons of coal, cubic feet of gas, and, of course, gallons of fuel oil are the units in which you as individuals and the industry of the Nation pay their bills for energy. But certainly the industries that provide us with that energy and our understanding of their problems must go far beyond the mere payment of our monthly bill if we in the future are to be able to power and fuel the civilian economy and the war machine in any national emergency.

Thank you.

QUESTION: Is anything being done toward harnessing the Mississippi for hydroelectric power?

COMMANDER DAVIS: I don't know of any developments along that line.

QUESTION: We have projects on the Missouri and a few other rivers like that. I was wondering if any thought had been given to that project

COMMANDER DAVIS: I know this question cuts across the work of Mr. Swaren.

MR. SWAREN: The answer to that question is that the Mississippi has an entirely inadequate slope, just barely sufficient to carry its own silt and, below the junction with the Ohio and Missouri, particularly, there will never be any possibility of hydroelectric power.

QUESTION: In connection with that last question and the slope and silt problem, I have read in various places that one of the problems associated with these new dams they are setting up is the silting up of the dams and the possibility that the dam will silt up to the point to keep out water in 30 to 40 years. The thought is that it might be possible to dredge those areas in the back of the dam. Have you heard anything about that project?

COMMANDER DAVIS: No, sir, I haven't. How about that, Mr. Swaren? Will you give us something on that?

MR. SWAREN: That problem has been very serious, but the Soil Conservation Service is getting in its work all over the country and the rate of silting is decreasing. Some of the dams that were built early in the Reclamation Service have lost an appreciable portion of the storage capacity, but, with the widespread operation of the Soil Conservation Service, that is slowing down. As to the dredging, that could be done, but it is an expensive proposition. One thing that is being done is to always provide an area for the silting in the bottom of the reservoir.

QUESTION: You mentioned the advantages of interconnections of power sources. Out in the Northwest they have a big power pool. We received our power in Astoria from Bonneville, but every once in a while we would lose power because someone felled a tree across high-tension wires or someone took a pot shot at one of the insulators. It seems to me one of the dangers in trying to go into interconnections is that Grand Coulee dam supplies over half of the power that supplies the Northwest power pool, and if someone should put out the switchyard there at Coulee Dam, I should think that would create a lot of havoc in the Northwest.

COMMANDER DAVIS: Of course, what you brought up is the whole problem of sabotage which exists every place in the country. I don't think it is feasible to guard against everything.

QUESTION: But it looks like more emphasis should be placed on locating a greater number of smaller units to serve individual areas rather than depending so much on interconnections.

COMMANDER DAVIS: From what I have been able to gather a 100-percent perfect system of interconnections would almost obviate what you have just mentioned--if it were economically feasible to have 100 percent interconnections.

QUESTION: Have you seen our switchyard at Coulee? It is a very small area but it could put out half the power supply when it is already short.

COMMANDER DAVIS: It certainly could, and of course you have mentioned a point in the Pacific Northwest which is actually degenerating so far as reserve capacity is concerned. It is going downhill, and it is expected to be deficient next year and the year following. They have two interconnections, a small one into British Columbia, and one from Oregon into northern California. I believe it would be feasible, if they had a hookup to the East, to take care of even that problem of putting out Grand Coulee.

QUESTION: The McNary Dam at Umatilla Rapids in Oregon should be nearing completion in the next couple of years and it is a tie-in that might obviate the knocking out of Grand Coulee.

COMMANDER DAVIS: Well, of course, all that the Umatilla Dam is going to do is to stave off a greater deficit in the Northwest than would normally occur. The Pacific Northwest is interesting in that it is the only area where the power commission estimates the power requirements versus production loads on the basis of the fact that the load will not appear because industry knows that the power isn't going to be available. In every other region, the Federal Power Commission assumes, and has in the past assumed rightly that, if industry potentially was going to move to a new area or was going to hookup in a new area, the power would be available when the industry was completed. This is not true in the Pacific Northwest. Industry won't go in because it knows it can't get the power.

QUESTION: As it is now, the aluminum industry has to shut down part time when a peak load is hit. Aluminum is one of the most important industries.

QUESTION: How do rates to consumers compare in the public projects as opposed to the private electric energy producing plants?

COMMANDER DAVIS: I quoted that as being one of the reasons given by proponents of government power. Actually, consumer rates vary widely throughout the United States in a comparison of the Government versus private rates. I think Mr. Swaren would back me up in saying that an over-all nationwide survey would indicate that private power has the edge. Usually what you find is that government power--where they do have low rates--is so much lower. It is a very dramatic rate that could make the headlines, but it is not true on a nationwide basis.

MR. SWAREN: That is substantially correct.

QUESTION: You mentioned the comparison between Federal development of hydroelectric power and private development. Isn't one factor in the lack of interest in development or the lack of ability to raise capital to develop hydroelectric power by private industry the Government's attitude, especially in the case of monopoly? Recently, we have seen lots of big corporation holding companies broken up, especially Commonwealth and Southern which Mr. Willkie headed. That has destroyed the confidence of investors in putting up the money, and it is driving them to Federal developments. It is also true of the Puget Sound Electric Company, I believe, up in the Northwest. One of the reasons the private investor hasn't gone into further development there is because of the breaking up of the big combines up that way. Is this good for the country? In your opinion, when we do go into government control of a basic power source, such as electricity, do you think this lack of confidence could be overcome if we made it more attractive to private investors to the point where we could get further development in the power field by private investors?

COMMANDER DAVIS: Well, of course, there you are up against an administration policy which is in support of federally generated power. However, you can't solve this private versus government development on the basis of whether you talk socialism or what it is. You have to talk about whether or not it is doing the right thing for the American people.

We had an incident--in the Pacific Northwest again--where there was opposition to the construction of both Bonneville and Grand Coulee: "Why are they spending all those millions of dollars? Nobody will ever use the power." Now they have a power shortage, which would indicate that the Government was right in that case.

However, when you go back into the past and investigate the extent of the development of electric power in this country, the curve has shown no great change in form or shape since the Federal Government got into the power business, which would indicate that the private company was providing power at a satisfactory rate. I am sorry; that is about all I can give you. You can get into a real argument.

QUESTION: In connection with this rate, if the government projects used the proper depreciation, if they had to pay interest on their initial investment at the capital investment rate the private company has to pay, and then pay taxes on top of it, the rates in most cases would be in excess of the private company's. Is that true? Have you looked into it?

COMMANDER DAVIS: I think unquestionably that is true.

QUESTION: In most cases hydroelectric projects are purely political rather than economic, in that, except in favored cases where natural conditions give you the head or the fall, the cost of construction with its attendant capital costs far exceeds the gain that you may get by having the hydrofuel.

Another big item that goes into hydroelectric projects is that in most cases they are located so far from the actual load center that your capital cost and the cost of transmitting to your load center makes it undesirable, whereas with coal and gas you can put the steel plants right in the load center and cut down on distribution--put them where you need them.

COMMANDER DAVIS: I think with regard to the use of coal, there is plenty of room for improvement in the use of coal. A great deal of work is being done on that. I think undoubtedly most power plants being constructed today are with these new methods of using coal.

QUESTION: I can't sit down in the face of that previous remark. I am familiar with the hydroelectric plants in the Pacific Northwest. I have just come from there. The Bonneville Dam is a good example of the economics of government power plants because it is free from competition or complicating factors. The dam was built, of course, without paying taxes, but was amortized, paying interest at 3 percent on the investment, which is about half of what the private power companies would have to pay. The power is sold at two mills a kilowatt hour, which is only a small fraction of the hourly rates of power in any other part of the country. The retail rates are the lowest in the country. The second lowest is in the TVA--except for the natural gas area in Texas. There, I think they are about the same.

As to the economics of the dam, it pays off this two-mill rate, all the cost of the investment including the transmission lines amortization, interest from the time of construction, operation and maintenance costs, and returns a net cash return to the Treasury of two million dollars a year. It is only one of the few government operations that pays cash bonuses. It will be amortized out well within the life of the project. So you can see that this government

enterprise is actually giving the lowest rates in the country and also returning a cash return. There are additional charges that a private power company would have to pay which would probably add about 2 or 3 percent to the interest charges, and also add a heavy tax burden. But even if you add those to it, it probably would be true that it would be much lower than the private companies could do.

So far as distance from points of use, the main load centers in the Pacific Northwest are in the Puget Sound and Portland areas. The best hydroelectric plants available are centered within a couple hundred miles farther east, generally speaking, on the upper Columbia River, and the cost of transmission is approximately one mill per kilowatt out of that two. So as far as that is concerned, it is very much cheaper to build those dams where the dam sites exist rather than to build much smaller and less efficient hydroelectric plants or even more expensive thermal fuel plants in the immediate vicinity. On a straight comparative basis in the Pacific Northwest, far and away the cheapest form of production of power no matter who finances it, is in the very large multiple-purpose development and not in any of the thermal developments or any of the alternate sources.

QUESTION: Commander, one of the sources of hydroelectric power that you haven't discussed is a rather controversial one and that is the use of ocean tides for the generation of electric power, such as found at Passamaquoddy. Could you give a discussion of this type of project?

COMMANDER DAVIS: I am sorry, I cannot. Mr. Swaren, can you tell us about tide uses?

MR. SWAREN: There may be some places where tidal power might be developed economically. I think Passamaquoddy would be one of them. But the cost would be very great. Tidal power is nothing new. There have been tidal water wheels operating along the coast of England for upwards of a thousand years. They operated intermittently. They gradually have been driven out. At Passamaquoddy there is an opportunity to store during the period of high tide and release through another chann thus getting adequate power. From an engineering or a technical point of view, Passamaquoddy is completely feasible. It is purely a matter of economics. There are many other places where that situation exists, but generally speaking the possibility of using tides economically is just no in the cards.

COMMANDER DAVIS: I think, too, when you consider hydroelectric projects, as I mentioned, having a feasible capacity quadruple the present output, it puts tidal power into the background.

MR. SWAREN: I would like to say one thing in reference to the discussion of the Pacific Northwest. I am not so familiar with the situation in the Pacific Northwest as I should be, but in all of these hydroelectric projects--Passamaquoddy should be a good example of it--private capital would be pretty hard put for a speculative enterprise to get its capital for less than 6 percent, and under our present regulations of the SEC, it would be necessary to have all the necessary capital in hand before construction started. Obviously, that capital couldn't lie there idle. It would be put in the great money market on short-term notes, but at a very much lower amount of interest than the company owning it would have to pay for it, regardless of how it was obtained. Then with the length of time that it takes to build a project--I think Grand Coulee took something like twelve years from the time construction started until it was completed and Passamaquoddy probably longer--there might not be a market for stock and it would take some time to get in the black.

Now this interest on construction is compounded, and paying compound interest on its construction costs puts a burden per kilowatt hour of production on the private enterprise that would make it impossible for private enterprise to reach the low rates that are reached by the public power plants.

I turned down Bonneville in a survey that I made in 1916 and early 1917 purely on that score, that private enterprise at that time would have to pay 8 percent; it would have been at least seven years before construction could have been completed. It would have been ten years, probably, before we would have been completely in the black. Well, ten years compound interest at 8 percent would be a tremendous burden, so it was obviously impossible to finance it although there were New York capitalists who were perfectly willing to put up the money and gamble with it if there was any chance of paying out at all.

QUESTION: I think we are looking for too easy an answer to this public ownership versus private ownership business according to these large hydroelectric projects. I know in the Central Valley Authority of California, with which I am fairly familiar, there are three conditions primarily: a water condition in which the southern end of the Central Valley, which is about eight miles long in California, is practically drying up. There is excess water in the northern part; there is an extreme political condition in the state, whereby the people in the South want water and are unable to get it other than through the reclamation project or the water-conservation project which are in the North. They also have a need for water for irrigation there, and the hydroelectric part of the project is secondary. There have been no objections that I know of on the part of private power interests in California against the project as a whole. The only objections they

have raised are the ones with regard to the distribution of power over competing Federal systems. The private power interests feel that the power should be distributed over the local--I believe it is the P.G. and E.--system which operates throughout the entire area.

The system, as it is set up, is so large and so complex with regard to the water-conservation and flood-control aspects that it would be impossible for any private corporation to undertake the project. As I say, the private people, both republicans and democrats, conservatives and left-wing, have favored the project, and the only argument has been over the distribution of the power generated as a by-product of these other primary needs. So I repeat my statement--I don't think the question of private ownership and public ownership is very large in the operation of projects such as TVA--and I don't know enough about TVA to make that statement--but I do know the Central Valley is an example of that problem.

QUESTION: To crawl out of the controversial and back into theory for a moment, I believe, Commander, you made the statement--and this would be purely speculative, of course--that the generation of atomic power would run about equal with the cost of generating conventional power. Such articles as I have read seem to indicate that, on a fuel basis, the cost would run about the same, but that the cost of plants for converting atomic power would be tremendously greater than the conventional plant. For example, one estimate was 25 million dollars compared to 10 million dollars for the conventional plant of an equal generating capacity. Do you have any further comment on that?

COMMANDER DAVIS: No, except to say that you are entirely correct, it was a speculative remark, but it was on a fuel basis. As a fuel, atomic power, nuclear energy could in the future conceivably be produced at a cost comparing favorably with present fuels, but the cost of the plant for converting that fuel is, as you state, much greater.

QUESTION: In regard to interconnections of these power systems, how far is it economically feasible to transmit power, due to leakage, wastage in the transmission system? Would it be feasible, for example, to connect northeastern sources with western sources?

COMMANDER DAVIS: No, sir. The Colonel can tell more about actual tests, but I do know from what I have read that they would never transmit it for any great distances. To make a stab at it, I would say not over 500 miles, but transmission is quite simple when one system transfers its excess power to the next, and that system passes it on. That can go just as far as you want it to go, as far as you have lines to take it. But, generally speaking, it is not feasible to transmit it over great distances.

MR. SWAREN: I would like to say something on that because there is general misapprehension as to the possibility of transmission. We have a very exact law, known as Kelvin's Law, which is the greatest economic law that has ever been written or which has ever been evolved, whereby a power line can be so erected that it will never lose money. There are many complications--I wouldn't go into them--but coming down to the actual transmission distance, if it is a fuel-powered plant, a steam plant operating with coal, if you are going to transmit farther than 125 to 140 miles, you had better haul your power in a coal car. Even with increased freight rates that would come in, it is still cheaper to haul the coal in a coal car. There are many other factors which enter in.

Of course, water power has to be brought to the center or carried to the center. It is just a question of whether you want to lose your money in the cost of transmission or whether you want to lose it in the interest on the investment of the line. If you want to make the lines big enough and heavy enough, you could transmit almost any distance with reasonable loss of power. They are operating constantly at Boulder Dam, which is approximately 285 to 300 miles, and they are doing it very efficiently, but it is because of the unusual economic conditions that exist. It is purely an economic problem.

During the war, for a short time there was a shortage of energy at St. Petersburg, Florida, and the only plant at that particular time that was not carrying the fullest possible load was the Twin Branch resource up near Chicago. By putting in a system of picking up, as Commander Davis explained, each plant saving a little out of its area, we managed to get 5,000 kilowatts into St. Petersburg. But in order to carry that 5,000 kilowatts, Twin Branch increased its load 12,500 kilowatts, and I would hate to figure out what it cost in dollars and cents for taking care of the tourists in St. Petersburg for a few days.

QUESTION: In connection with the exploitation cost, we have heard about the possibility of burning coal below ground and utilizing the gas generated. Is anything further being done along that line that you know of?

COMMANDER DAVIS: I can't give you any recent figures. We put on our course in Birmingham last year. They took us out to this project being sponsored jointly by the Bureau of Mines and the Alabama Power Company, in which they are burning coal underground at Gorgas, Alabama. At the time we were there they were getting about 36 B.T.U.'s per cubic foot, which is nowhere near what they need to economically use it as industrial gas. However, there had been times when they had obtained as high as 96. The lowest grade of commercial gas is around 150--if they can get that high. But the fact that they had gotten 96 under very selected exploratory conditions showed promise.

I might take a few minutes to tell you something about that operatio They have a coal seam which is, I would estimate, at the entrance about four feet thick, and they chose this spot, obviously intentionally, where it runs under a crest of the hill. They drove their hole into thi coal seam and then at the top put down, at spaced intervals, ordinary pipe lined with firebrick. Then by a system of shutting off between the blowholes, as they call them, they could introduce air down one and set the coal afire, and expect to get exhaust gases out of the top. They found out, after they went in and investigated, the only thing that permitted this operation was the fact that the rock on the top in the cente of the hole would melt and fall down and form a mass which kept forcing the air out against the sides of the coal seam. In other words, if that hadn't happened, they would have had to continually put more and more ai into it until they would get to the point where the compressors were not big enough and they couldn't supply enough air. The only thing that permitted this was the falling down and the caving in of the roof, keeping the air forced out against the sides of the coal seam. In that way, they have attained up to 96 B.T.U's, which is near what they must have to make it commercially feasible. It is a problem of so much loss, having to introduce so much air, and so much oxygen coming out of the exhaust flue.

COLONEL WATERMAN: Commander Davis, we thank you very much for a ver thoroughgoing and enlightening presentation.

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