DISCUSSION ON "ELECTROCHEMICAL INDUSTRIES AND THEIR INTEREST IN THE DEVELOPMENT OF WATER POWERS" (ADDICKS), "WATER POWER DEVELOPMENT AND THE FOOD PROBLEM" (CUSHMAN), "RELATION OF WATER POWER TO TRANSPORTATION" (STILLWELL), WASHINGTON, D. C., APRIL 26, 1916.

David B. Rushmore: As we all know, the world in its advance has been marked by certain definite epochs which have been associated more or less with certain inventions. Unfortunately, not all of these have been recorded in the United States Patent Office, because when man invented power and the use of powder, and the use of fire, the Patent Office was not organized.

It is interesting to see that the civilization which we have in this age is sharply distinguished by certain features, and to my mind the particularly distinguishing feature of this age (which we will say runs back something over one hundred years) is the large use of energy and the great advantage which has followed from its use. Our whole civilization is based on the fact that we consume an amount of energy per individual far in excess of the energy which that individual can evolve.

If we had a complete statement of the facts, we would find that in the last one hundred years there has been an enormous increase in the use of energy per inhabitant. The world, and particularly the United States of America, in the past hundred years has gone through a rapid cycle of activities. Their sequence has been exploration, hunting and fishing, lumbering, mining, agriculture, and finally industry, including manufacturing.

The United States is approaching the industrial age, and that is one of the reasons for some of the economic diseases which we may or may not be able to ward off. The food products are falling off, exports of manufactured products increasing. This indicates a change of flow of commodities.

Now, this being an industrial age, and the age being founded upon the consumption of energy, it is rather interesting to show in brief outline what our principal industries are. At the top stands slaughtering and packing, and it is followed by foundries and machine shops, lumber and timber, iron and steel, flour and grist mills, printing and publishing, cotton goods, men's clothing, boots and shoes, woolen, worsted and felt goods, tobacco, car shops, bread and bakeries, iron and steel blast furnaces, woman's clothing, copper smelting and refining, malt liquors, leather, sugar and molasses, not including beet sugar, butter, cheese and milk, paper and wood pulp, automobiles furniture, petroleum refining, electrical machinery, distilled goods, hosiery and knit goods, and a great many others, in which the value of the annual production is over $100,000,000.

Now, if we withdrew the energy from the world, if we for a moment withdrew the energy from our civilization, we would go down like an infant whose food is withdrawn from it. That

means that our civilization is dependent on energy, and anything which affects the production of energy seriously affects the continuance of our civilization.

Water-power is one of the sources of energy, fixed as regards location and fixed as regards certain attributes and factors which it involves. Energy we must have for our civilization. And what is the attitude, or what is the relation, of the different factors of chemical industries, of food production, of transportation to the source of energy on which they will draw?

First, the problem goes back to the one which we have often considered, that of conservation. The only way to conserve a waterpower is to use it, and the only way to conserve a coal supply is not to use it. A question that is not often raised, but is involved in all of the papers this afternoon, is the great improvement in steam generating apparatus, both as regards the decrease in cost and the increase in efficiency, but we make a great mistake in making use of the cost of coal instead of the value of coal. If the last ton of coal in the world, the final ton, before we go into something else, cost 80 cents, we can all say that its value will be worth more than 80 cents, so that the value of the coal and oil supply which we are not conserving in any way, in fact, we are now wasting it, by allowing such waterpowers to go unused as might be economically developed cannot be determined by the present cost of coal. We are detracting just that much from some future condition of civilization.

Now, if the government, if a combination of individuals, committed some act which robbed our civilization of some of its food supply, or of some other necessity equally great, or even of some of its pleasures, there would be protest. Just that same cause for dissatisfaction exists against ourselves, for we are all involved, not utilizing in the best way we can the sources of energy which are at hand, and whose use would not diminish their worth, and persisting in the use of sources of energy which may ultimately become exhausted. Take into consideration the per capita increase in coal consumption, increase in commodities, increase in industry and transportation, we can see that it cannot go on forever.

The question of waterpower and its relation to these different energies is this—waterpowers are, some of them, susceptible to present economic development. My personal belief is there are many waterpowers in the United States where power can be developed at the power house for much less than steam will ever be capable of being developed, but water power at the power house is different from water power one hundred miles away. Many of our electrochemical industries could be located at the power house in so far as the simple question of power is concerned. Many plants are already so situated, but in the long run the question of the transportation of materials controls.

I do not place the blame for the lack in waterpower development on any one in particular. As I see it, and under the situa-

tion as it has arisen, the people do not understand its value. They sit still, until some one devises and works out some practical way of doing things. When the people are educated, so that they can understand what is going on, then they will take action with regard to the development of such problems.

The railway electrification which has taken place in this country started in the East. The first railway electrification was practically forced by legislation, due to an accident in New York, and that has meant that the railway electrification has been largely based on steam power, on energy derived from coal. There has just begun a larger railway electrification. The transcontinental trunk lines have taken up electrification. The Chicago, Milwaukee & St. Paul is the first one to go into the use of energy derived from waterpowers. They are electrifying 440 miles of their road between Harlowton, Montana, and Avery, Idaho, the first half of this being completed and in successful operation. Some of the results secured are that the cost has been reduced, the weight of the trains increased, and the speed of the trains increased. Prior to the electrification, a considerable proportion, I do not know the exact number, but I think it was not far from 15 per cent, of the locomotives on the railroads were simply hauling fuel for the other locomotives to use. They have been cut out. One of the greatest dangers on the mountain lines is the braking of passenger and freight trains going down hill, and the life of the brake shoe is very short. With electrical motors there is nothing to wear out, not only is the braking done without mechanical friction, but power is brought back in the line.

The very great likelihood is that this road will soon electrify all the way through to the Pacific Coast, and that will force the other railroads to electrification, and force the utilization of these waterpowers, if there is any way of bringing that about. It will require a vast investment, which the railroads have got to provide. If they cannot afford it, they must attract this investment in order to bring about this use of energy. When this waterpower is utilized there will be a saving of other forms of energy to civilization, a saving of coal, which will not have to be burned up until some time later.

The point which we are all looking at is this—the relation of all these factors of waterpower utilization to our modern requirements of consumption. We must bear in mind that once a waterpower is developed into practical operation its supply of energy is continuous and not diminished by time. Some sources of waterpower energy are sometimes inaccessible, sometimes they are expensive to deliver, and sometimes they have a very intermittent stream flow. In certain cases the waterpower can be tied in with another system, a steam station, which, with the waterpower, will develop power for transmission over long distances. In some cases the waterpower plant cannot be physically or economically separated from the steam plant, as a

matter of fact, and the question is always before us how best to bring about the most economic utilization of such water-powers and how best to conserve our fast diminishing coal supply.

F. A. Lidbury: There seems to be no doubt from the papers we have heard this afternoon that whatever other applications for water power may be successfully prosecuted in the future the consumption of water power by the electrochemical industry is one that can certainly, given favorable circumstances, be counted upon to grow very considerably. Mr. Addicks has covered very briefly and very concisely the large number of factors which enter into the employment of water power for electrochemical purposes, and the paper is worthy of study because among those who are not closely familiar with conditions in the electrochemical industry it is common to put the whole of the electrochemical industries in one class as power consumers. They are extremely diverse, their requirements in power are extremely diverse, and the relative importance of the factors of power, labor and other items is also extremely diverse.

We have electrochemical industries which have not succeeded yet in obtaining a footing in the United States because their requirements in power are enormous in extent, and because they require the power at a price at which this country is as yet unable to furnish it, and probably always will be unable to furnish it. We have, on the other hand, industries which you could not drive away from this country no matter what the power conditions were, industries such as that Mr. Addicks is associated with, the refining of copper, in which operation the cost of power is such a minor item that they generate the power by steam.

These two classes of electrochemical power consumers, however, stand outside the limits of that group of electrochemical industries which is chiefly located at Niagara Falls in this country. Mr. Addicks inquired why, in view of the fact that the price at which Niagara Falls power is now sold can not be considered low, and in spite of the fact there is a shortage of power at Niagara Falls, these industries do not go to other places. The answer is—they stay there because they are there. Why are they there? Why did they go there? They went there because at the time when these industries were being developed, at the time of their birth, Niagara Falls offered them the most favorable ground which they could select for their development; it offered them a source of power which then appeared to be reasonably large for their needs, a source of power at a cheap price, and a source of power of an extremely reliable nature. To a great extent it is entirely owing to the fact that at the time these industries came into existence that source of power was there in that form at Niagara Falls that these industries now are at Niagara Falls and not, to a large extent, in Europe.

Mr. Addicks inquired why they do not move from Niagara Falls to other parts of the country, particularly to those regions

where they could obtain power from steam at a cheap price. That brings me to a point which Mr. Addicks might have expressed a little differently. He compares the cost to an electrochemical consumer of water power and steam power, and taking the cost of water power around $20 per horse power per year, which he presumes to be the present Niagara price, compares that with what he conceives steam power can be generated for in large units. In one case he is dealing with a selling price at one's plant including a profit; in the other with an actual cost. The answer to Mr. Addick's question is that these plants have been moving and are moving from the country. Those of you who are familiar with the conditions of the electrochemical industries of Niagara Falls know that when the restriction was put on the power developments at Niagara Falls, in 1906 and 1907, an emigration of electrochemical plants producing materials not for foreign markets but for American markets started and has been continuing ever since. That gives, as far as one can answer the future by surveying the past, the answer to Mr. Addicks' question—Why do the plants stay at Niagara Falls? The answer is they do not, and they will do so, apparently, to a less and less extent. The reason for this is, of course, as everyone knows, that there is at present a power famine at Niagara Falls, particularly on the American side of the border.

The location of such plants at other points in the United States where cheap water power may be available is only possible in the majority of instances where these water powers are most favorably located. I made some calculations a few days ago comparing the cost of water power with the costs of freight on finished electrochemical products. A reasonably cheap freight rate, as you can all appreciate, is vital in the electrochemical industry. It appeared that a thousand mile haul to the center of the area of distribution would be equivalent to a difference in the cost of power, as a rule, of from $10 to $20 per horse power year; in one or two instances much more.

So far as the electrochemical industry is concerned, this question of water power is a vital and pressing subject. Unless the electrochemical industry is able to get the power as it requires it in economically available locations, that industry will relocate, and to a great extent will relocate abroad. By the time you have converted power into electrochemical products, and utilized those electrochemical products, and have figured what it would mean to this country to stop the progress which those electrochemical products have made possible in the fundamental interests of this country, Mr. Rushmore's $100,000,000 a year will look like nothing.

Henry G. Stott: The question that seems to run through all of the three papers might be put in a few words—How can we get power cheaper? Is there any way in which we can develop power cheaper than it is being developed at present, which will admit of the development of the electrochemical processes? If

we go back perhaps we will see why the electrochemical industries today are tending to move away from Niagara Falls.

Fifteen years ago Niagara Falls was unquestionably producing power more cheaply by water than by any other method which could be found in this country. In the meantime the evolution of hydroelectric equipment has gone on quite slowly, as it had a very high initial efficiency. Let us look, on the other hand, at the steam plant. The hydroelectric plant, let us say, has made 10 per cent advance in fifteen years, but in capital cost it has not made any advance at all, if anything the capital cost has gone up, as the cost of labor and material has run up.

Let us look at the steam plant. To begin with, the capital cost of the steam plant in fifteen years has been a little more than cut in two. The next point is that the steam plant is now making power with approximately one-half the coal required fifteen years ago. Those are two enormous points of advantage.

I was very much interested in going over a situation recently which involved tacking on, as it were, a steam plant to a large hydroelectric system. It fell to my work to look into the economics of the situation as well as the engineering possibilities. After going into the situation carefully I came to the conclusion that up to a certain load factor we can today produce power more cheaply, with a lower overall cost, (including fixed charges, and operating cost), by a steam plant than we can by any hydroelectric plant now in existence applied to this particular case.

The overall costs of power were approximately equal at a load factor of 60 per cent. Above that the hydroelectric plant began to show a little better results than the steam plant. Below that point the steam plant was better relatively as the load factor went down.

Now, what we learn from these facts, is simply this—that if we want to produce power at a lower cost than we can do today by hydroelectric plants, we must use some combination of steam and hydroelectric power, the steam plant for the peak loads and the hydroelectric power for that part of the load having load factors of over 60 per cent.

With this combination, as I found in the investigation referred to, the total cost of power, showed a reduction over what could be produced by either steam power or hydroelectric power alone.

There is one feature that Mr. Rushmore touched on, which it seems the whole discussion should go back to, and which we should present to our legislatures and explain the situation as clearly as possible to them; that is, if we can produce steam for the average purposes, for the use of those industries which involves the use of a load factor considerably below 50 per cent, why bother with hydroelectric power at all? There is no use in going into it where the load factor is below 50 per cent. There is hardly a single hydroelectric power left which it will pay to

develop if the load factor is below 50 per cent. The conservation of our limited supply of coal, however, demands that every possible means of reducing the annual consumption of fuels should be enforced for the benefit of posterity.

At the time of the last census there were approximately 1,750,000 kilowatts developed hydroelectrically in this country. I wonder if we realize what that means? That means that approximately 20,000,000 tons of coal per annum are saved to posterity. That, it seems to me, is the real point that we should drive into the minds of our legislators if we can,—we should do everything possible to save our limited supply of fuel.

The improvement in the efficiency of steam plants has been remarkable during the last fifteen years, so much so that, as I said before, the total cost of power has been cut in two. I think there is a possibility of going still further, there is perhaps 10 or 15 per cent left to work on with the present cycle, but the important thing, it seems to me, is to stop the use of coal wherever we can do without it, by developing our hydro power. That would look like a good situation for the government to consider in aiding rather than retarding the development of hydro power.

Gano Dunn: The average load factor of all the central stations in the country, including water powers, according to some government figures I recently saw which I trust I interpreted correctly, is under 26 per cent, which drives home the importance of Mr. Stott's remarks about the difficulty of a water power competing in the power market with a steam power when water power is only good, or at its best, at high load factors, and cannot hold its own at low load factors with the present efficiency of steam production.

Those interested in the water powers are keenly desirous of finding some way of getting the cost of power down, in a way that might be regarded as intrinsic, as distinguished from the way Mr. Stott referred to and others have referred to of supplementing the water powers with some auxiliary. An intrinsic way would be the development, of processes that could take secondary power, whose costs of interruption under the secondary power plan would not more than offset the gains due to the cheapness of secondary power.

I hope we can get a full discussion from our electrochemical friends in regard to the degree of interruption permissible, and its economic effect in order that we may study to what extent secondary power can be used to absorb the now wasted surplus power of a great many hydroelectric developments. Such absorption would not only give cheap secondary power but would have a reaction reducing the cost of the primary power; in other words, both services would be considerably reduced in cost.

Mr. Stillwell significantly points out the changed equation between steam power and water power in application to the electrification of railways. It is unfortunate that three-quarters of our power consumption is in the east and three-quarters of our

[illegible] water powers are in the west, but if we want to do something about the water power situation, and do it promptly, we have coming into the realm of doubt, there is a large amount of work that can be done by attacking those situations where the water power is actually cheaper than steam power on account of the high cost of fuel, and where the railways would benefit enormously by using such water power as is available. One reason why we have not used it in the past has been quarrels among electrical engineers as to which system of equipment was the best. These questions are very rapidly settling themselves. The railroad men, who are conservative, have been deterred from adopting electrical systems, not knowing how soon they might be changed. In introducing electrification upon the railways it has required large amounts of capital, and capital has been difficult to raise in the last decade on account of rate regulations and similar restrictions, as well as on account of the general attitude of the public; and the railways have felt that it would be better to "suffer the ills they have, rather than fly to others they knew not of." It is for us to show that this time has passed, and that the time for the more general electrification of the railways is at hand.

If those interested in water powers, and if those interested in the electrification of railways, especially in the Pacific and mountain states, will devote their energies to bringing the various interests and engineers together, so that there may be mutual understanding, we can at least make a good start by using such water powers as at present can be used to advantage. Once we started, there would be indirect advantages of electrification that will start a general movement and will show that these indirect advantages have, perhaps, been underestimated, and there will then be equipped with water power many railroads which now think they are not quite ready for the equipment.

J. B. Whitehead: It has been emphasized that the cost of electric power from steam plants has been decreasing while that of power from water plants has remained practically stationary. The explanation lies in the general low efficiency of steam plants, offering, therefore, opportunity for improvement and also the lower first cost due to the development of the steam turbine.

The question arises would it in any way be possible to improve the showing of the hydroelectric plants in the same directions if efforts corresponding to those exerted in the steam problem were also directed to the water plants? While improvements in the efficiency of water power plants, comparable to those possible for the steam plant, may not be looked for, it should be possible, in certain types of plants, to reduce the first cost of the station. Savings should be possible in an aggregation of electrochemical industries and a water plant in which the generating station would operate at moderate voltage and with the elimination of high-tension control and protection. It would also appear not impossible to have the generating station

under these circumstances, practically of an out of door type, with such simplified control as would be necessary, located in one of the industrial plants. While this does not attack the larger cost of the dam and reservoir it seems to offer some opportunity for further reduction of cost of the station.

L. H. Baekeland: The standpoint of the chemist or electrochemist can be summed up in this way—we know how to take care of the chemical side of the proposition, but we are enormously hampered by the lack of cheap power. We hoped that you, electrical engineers, were going to help us in our needs. But when you talk so hesitatingly about the possibility of our water powers being cheapened, and, on the other hand, when we consider that our increasing steam power plants will exhaust so much the sooner our available supply of coal, I must say that I feel somewhat disappointed.

The situation is as follows: In some of our electrochemical industries, we are suffering from lack of abundant power even at high prices, say $20.00 a horse power year. The case has been very well stated by Mr. Lidbury. There are certain electrochemical industries where we can afford to pay relatively well for power, provided we get the power at the right locality, the right point for the market, the right point for freight, the right point for raw materials, and the right point for labor. Niagara Falls is one of those places, but the amount of power produced is all taken up, and further development is prohibited by law. Then there are some industries which could not live in Niagara Falls, even if you could supply them with all the power of Niagara Falls, because the price of power there is too expensive, and I cannot better illustrate this than by taking the example of our contemplated nitric acid supply in relation to the defenses of the country. When it comes to making nitric acid for war purposes, it does not matter how much it costs, because it then can be made regardless of cost. Nowadays the people who are fighting in Europe do not figure how much it costs them; someone else will have to pay for that. For example, phenol which in times of peace is rated expensive at seven cents a pound when it is to be used for peaceful industrial purposes was found cheap enough for the making of explosives in time of war at $1.75. The same thing can be said of nitric acid. The Germans, when they wanted nitric acid, did not discuss the question of the cost of power; they simply erected steam and gas power plants as fast as they could so as to become independent from Chile saltpeter in their nitric acid supply. But there is a more important question in connection with this subject, a subject of far-reaching national importance, and that is the production of cheap nitrogen-fertilizers. I am sorry to have to say that in connection with the production of cheap fertilizers, the problem looks much more difficult, because for this purpose, power should not cost more than five or six dollars per horse power year.

There is one point of view which has not been brought out

here; our more expensive water powers in the United States, as compared to those of other countries, are mainly due to the fact that in this country there are always more contemplated enterprises looking for capital than there is money available. The business enterprises of the country are chronically short of money. They carry on so many enterprises and do this as quickly as possible, and this increases rates of interest; furthermore, our methods of banking are rather wasteful as compared with those of Europe. The result is that when we erect a water power the fixed charges which are incurred are much heavier than what they are in Europe for similar enterprises. Our rates of interest here are very high. In Europe people were glad to invest money at three per cent in various real estate enterprises, and in water power developments. In this country, by the time you float the bonds and give the usual rake-off to promoters, bankers and brokers, and after you consider a lot of side issues that are involved, your water power is already carrying fixed charges of $9 per horse power year, and this charge is fastened on the enterprise before you start to operate. This fact makes an enormous difference when we come to consider the cheapening of water power. Who is going to change this and how is it going to be changed, is a matter on which I cannot advise. Our bankers will have to use less wasteful methods and perhaps the Government may have to do its share by utilizing its excellent credit so as to obtain money at low rates of interest.

J. J. Carty: One of the purposes of this meeting was to call attention to the method of making the work of the bankers less wasteful—if that be a proper term to use—by establishing water powers upon a stable basis where the investor could know where he stood from one year to another. Money can be obtained in this country at low rates of interest or at high rates of interest, depending altogether on the certainty of return and the amount of return.

Owing to the obstructions which have been placed in one way and another about the development of water power, prudent investors and conservative bankers, whether they be located in Europe or in America, have found that only a high rate of interest would attract the people away from more stable investments into the vicissitudes of water power development. If I understand the character of these papers submitted today, and the general situation, the main object is to remove the uncertainties which entangling legislation has cast about the development of these water powers and then the bankers and investors will be in a position to reduce the cost of these hydroelectric powers by furnishing capital at a lowered rate of interest commensurate with the lowered risk, which would certainly ensue the moment that stability enters into the chaotic legislative condition.

L. S. Randolph (by letter): Mr. Stillwell overlooks one or two points in regard to the locomotive situation, which I think should be dwelt upon.

The largest locomotives that we have been able to get only give about 4000 or 5000 h.p. and that seems to be the limit for the present length of locomotive.

Six drivers in series, or coupled by one set of rods have been used but were not found successful, five are being used on some of the Western roads where very heavy grades are concerned, but as a rule four drivers coupled together or the consolidation type, seems to be the limit and in the Mallet many of these are running back to three pairs of drivers coupled together, although the Henderson Mallet on the Erie has four pairs of drivers coupled together, having three sets, making twelve pairs. This seems to be the largest locomotive so far and the problem comes to " what is the limit in length?" as it is practically impossible to increase the cross sectional area of the locomotive, and therefore increase its size in that way. It is as high now as the bridges and tunnels will stand and as wide, and any increase in that direction would mean an entire rebuilding of the permanent way.

So far, the voltages now used permit 9000 h.p. and this has been transmitted by one wire, two wires, of course, would double this, and with higher voltage and smaller amperage still greater h.p. could be transmitted, and with motors under each car, as in the case of street railway cars the limit is almost infinite.

Another point that should be considered in figuring on the economy is that the coal consumption is really a comparatively insignificant item. If one studies the development of the steam locomotive he will find that for years and years, in fact, up to the last five or ten years comparatively little attention was paid to the coal consumption. This was due to the fact that the addition of one or more cars would add to the income of a railroad enormously greater amounts than the cost of the additional coal; so that all the development was towards increasing weight, size, lessen track resistance, etc., so as to get the highest possible hauling capacity for a locomotive. Some five or ten years ago the limit of the size of the locomotive was reached, and therefore the limit of the size of train it pulled. Attempts were made then, not to reduce the coal consumption so much, but to get a larger capacity out of the boiler and a larger h.p. capacity out of the coal consumption. We had from this, the introduction of super-heated steam and feed-water heaters, which were adopted not so much towards the saving of coal as for the increased capacity.

The application of electricity to steam railroads is indicated at the present day wherever the density of traffic makes it impracticable to handle readily the traffic with the steam locomotive, as a case in point, it is stated that on the Elkhorn Electrification of the Norfolk & Western Railroad in West Virginia, four or five electric locomotives handle the work that required seventeen Mallets of the largest type.

Wherever such a state of affairs exists as just mentioned, electrification will give large returns on the investment.

Lawrence Addicks: I think we must all be struck in this discussion with the philosophic tendency which it has taken. It shows that the engineer of today has to be a political economist, a conclusion at which he has been too long in arriving.

As to Mr. Lidbury's discussion I think it is safe to say that power could be sold for $20 a horse power year from a large plant, meaning perhaps a 25,000 or 30,000-kw. plant, but I qualify that to this extent, that we assume the prices for fuel, labor, etc., that prevailed up to a short time ago, and not the high prices that are prevailing temporarily on account of the war situation.

As to what Mr. Stott said about the load factor, of course, a number of us in the electrochemical industry feel that we have a 100 per cent load factor, and the question does not enter there as in public utility work.

As to what Mr. Stillwell said about interruptions of service, my feeling is that it is not practicable to talk about diurnal interruptions, in order to decrease the consumption of power, of three or six hours a day—I do not believe it will work out satisfactorily, except in some possible case such as the carborundum industry, where the whole furnace is torn down after a certain number of hours run. I do think there is a possible solution, which seems a little fantastic. Suppose we took Niagara Falls and put the whole four million horse power in water wheels, and that it was agreed that the plant should be shut down every Sunday morning, for say six hours, so that we could turn the water back into the river. In this way you would satisfy everybody. You would satisfy the power people, because they would get the power which they require. You would satisfy the conservation man, because he would have the scenery, and he could see it once a week. It would satisfy the hotel man, because more people would come up to see the river turned back than came to see it running in full force.

Allerton S. Cushman: Mr. Addicks has referred to his impression that the gentlemen who have discussed these papers have treated them from a philosophical viewpoint. That has not been the impression made upon my mind by most of the discussions. It struck me that many of the engineers were principally interested as to whether water power or steam power would be the best paying investment under present load factor conditions. My own mind has been more exercised with the probable future needs and conditions of the country than with dividend prospects under present conditions. If it is true that we are to expect a population of two hundred million people in this country within the next half century or so, it is about time to begin to study the power requirements of the future and to discuss water power development from a somewhat broader viewpoint. For my part, if it requires for the time being a sub-

sidiary steam plant to make a water power plant pay, I would rather have it that way than allow our water to continually run to waste. This may not sound very practical, but surely there is such a thing as building and preparing for the future. Moreover our electrochemical industries need water power, and already in some cases are going abroad to find it. I am at least practical enough to realize that if we are to have cheap water powers we must have cheap money to develop them. The government can borrow money at low rates, or the government could guarantee or endorse water power bonds under properly safe-guarded conditions. I for one can see no harm in such a suggestion, and would advocate such a plan if I had the opportunity. To my mind it is one way of keeping the government out of business, but I confess I would rather have our government develop those water powers that ought to be developed than not have them developed at all. The government might build the dams and lease the power under proper regulation, but this would mean the use of government money, with the usual pork barrel danger. Under a guarantee plan, the government would use nothing but its credit unless some water power failed to earn the interest on its bonds. Why should Norway get cheaper money than we for water power development? Some way out of this situation ought to be found, for many people in this country believe that these things are worth doing and worth doing now.

L. B. Stillwell: The last speaker, Dr. Cushman, made a statement which it seems to me is fairly debatable from an economic standpoint. To my mind the proposition that the government should endorse water power bonds is economically as unsound as—possibly it is worse than—the proposition that the government should build a system of canals to parallel our railway systems. The government never yet has been able, I think, to father industrial enterprises or transportation enterprises with that degree of scientific discrimination which is essential to a right result.

Private capital in this field needs no endorsement by the government. What it wants from the government is security of tenure—definite title or definite lease—so that it can at the start before making its investment estimate all the essential factors which it must know in order to justify investment.

Until we have evolved a very different system of economic administration of government in this country, I should be sorry, indeed, to see the government embark upon a plan of endorsing water power bonds.

I do not know that there have been any points in my paper which have been discussed that I need refer to. Our president has touched with great clearness and with emphasis upon the point made by Dr. Baekeland in regard to the high rate of interest. I believe that the high rate of interest which we have to figure when estimating a water power development would be

materially reduced if we could secure a definite tenure and if we could feel sure that the going concern would not become an object of unjust attack through the power of taxation. It is the fact that these factors are today uncertain which in my experience frightens investors away from water power development.

The one thing that we need to do—we engineers and all of our citizens who understand the economic facts—is to educate the public and to assist our legislators to get the economic facts in proper perspective in order that we may secure legislation that will permit us to go ahead. It is nearly eight years now since the agitation began in regard to western water powers, and it would be hard to name a water power of importance that has been taken up and developed *de novo* during that time. There are a number of cases where plants have been extended, where a growing business and the fact that money was already invested compelled an extension, but the number of new ventures is not great.