DISCUSSION ON "HYDROELECTRIC POWER AS APPLIED TO IRRIGATION", SAN FRANCISCO, CAL., MAY 6, 1910.

President Stillwell: The possibilities opened up by the application of electric power to pumping water for irrigation in California, are obviously very great. A recent publication by the United States Geological Survey estimates the available water powers of California at 7,000,000 twenty-four hour horse power. Assuming twelve tons of coal per horse power per annum in 24 hour service, that power would require for its production by steam, 84,000,000 tons of coal, which happens to be approximately equal to the anthracite output of the coal mines of Pennsylvania. So vast an output of power, if utilized in manufacturing, would supply a very much larger power market than even California can hope to develop in many years. It is peculiarly interesting that many of these powers exist within practicable reach of land requiring water for irrigation.

A paper which was read at the recent Irrigation Congress at Albuquerque by Mons. Tavernier, Chief Engineer, Department of Public Works, Republic of France, deals with this subject and its conclusions are particularly interesting when considered in the light of similar experience by Mr. Hays and his company. Mons. Tavernier reaches the conclusion that even considered from the standpoint of power economy, it is frequently not more expensive to use water power to operate dynamos, which in turn operate motors lifting water by pumps to the land which requires irrigation, than to distribute water by ditches. According to his figures, the efficiency of the two processes in many cases is practically identical.

E. W. Paul: I would like to ask Mr. Hays in regard to his table given in his paper. I don't quite understand it. He has a plan here of eight and ten acre groves, ten years old, and to irrigate that requires a two h.p. motor. The experience of farmers in the south, with which I am familiar, is that they do not want to irrigate one row of trees at a time, but they want to flood the whole orchard at once. This requires considerable water. I do not think that a two h.p. motor would do that. I would like to ascertain whether they do irrigate the entire ten acres, or do they sit up all night changing the water from one row of trees to the next. I would also like to know if the company with which he is connected requires the motor to be taken off the line on the peak load, and if it does, how they overcome his objection to that feature.

J. C. Hays: The two h.p. motor is correct. Some of them have small reservoirs which will hold the water, and they run that motor continuously 24 hours, and they do irrigate probably ten or twelve rows a day from this little reservoir made of dirt, in some cases, they irrigate a very few rows at a time as they go across their orchard, and they figure that this flat rate will

keep them all the time. This dry bog country has to dry out before they can cultivate it. As to taking the motor off on the peak load—as irrigation is the only peak load we have, they work all the time.

F. V. Henshaw: Mr. Hays describes an electric power system which was apparently built entirely on a fore knowledge of there being sufficient underground waters to enable the plant to get its business by pumping for irrigation, and presumably before going into this project, the extent of those waters was very carefully determined. I think it would be interesting to learn from Mr. Hays the extent to which the underground waters of the San Joaquin Valley have been examined, and whether to-day it is known that there is a sufficient supply there, in all probability, to irrigate all of the land that cannot be covered by surface waters by gravity distribution. Another point occurs to me, regarding the cost of construction; Mr. Hays says: "If constant service is not absolutely necessary, what possible type of construction can compare with the flume?" I take it that the flumes are built very light, and the point is as to how long an interruption the farmer can stand under extreme conditions. We will say an orange grove, which is at a point where it needs the most water—how long can it be without water without serious damage.

J. C. Hays: I do not know the extent of the underground waters in our state. I have read several papers and reports on the subject but believe that the only way we can tell is to pump.

F. V. Henshaw: I thought you had been doing that.

J. C. Hays: Well, we have in some places. But you can hardly call that conclusive. We have been pumping in one district for ten years, and apparently the supply of water is not diminished. So it naturally looks like there is something there. The water shed of the valley is large enough to take care of the underground waters, and the formation of the deltas in these rivers is of such character on the east side that the water percolates very slowly. On the west side, I understand, there is a different condition where the water flows out very fast; consequently, we are liable to find variation in the wells, but there is a very little variation in the wells on the east side.

F. V. Henshaw: Did you find any wells that had a flowing head?

J. C. Hays: Yes, in what I call the valley portion. But artesian wells are not considered very good for irrigation. I personally do not know much about that subject, but I do know that there is sulphur, or something deleterious in the water, and I know of one peach orchard that was killed by it. As to the subject of the flume—I don't know just how long an orange orchard could go without water. They claim in that country that if they do not irrigate for about two weeks in a very hot season, the trees commence to show it. Most of the growers

claim that they can look at the trees and tell when they need water.

An interruption on the flume or the line, for instance, would not amount to over 24 or 36 hours, possibly 48 hours, and an interruption of that length would do no damage. Of course, during certain portions of the year, landslides cause some damage, but I do not remember of any landslides occurring during the irrigation season. They always occur in the winter time, and never during the irrigation season.

H. Homberger: The Mount Whitney Power Co.'s system is of particular interest to the hydraulic engineer, being a power system where 80 per cent of the power is generated hydraulically and 70 per cent of the power used for pumping. How entirely different the conditions are from those of the average commercial plant with a mixed load, has been most ably and clearly explained. There were a few points mentioned which I should like to be further enlightened upon.

First, the question of high price permanent construction as compared with low price temporary construction. It was stated that engineers of prominence have broadly condemned the wooden flume and the wooden pole line as compared with the tunnel and steel towers or reinforced concrete poles. Such a stand can only be explained by entire disregard of special conditions; there is no greater danger in engineering than unwarranted generalizing of principles of construction and wrongly applying what is good in one case to some other case where it might not fit in at all. Personally I am not in favor of wood as construction material and would rather see an inorganic material used. To be sure, 20 years is a remarkably long life for a flume, and I think not to stand alone with the statement that half that is nearer the average. Similar are the conditions with a wooden pole line. It seems to me, however that generally too much stress is laid on the difference in first cost and the fact not taken in consideration, that considerable expense is connected with the necessary continuous patrolling and maintenance of such structures, which if capitalized, would go a long ways towards providing for the higher first cost of a more permanent type of construction, which, as stated, will ultimately have to be resorted to anyhow.

A second point: Balancing reservoirs were mentioned at the head of the pipe lines; while the reservoir of the latest plant, the Tule River Plant, has sufficient capacity to operate the plant $1\frac{3}{4}$ hours under full load, at the Keweah No. 1 station it holds out only 25 minutes and at Keweah No. 2 even less than 19 minutes, which is certainly of little value in case of trouble in the gravity conduit system. The main function of the latter two reservoirs is stated to be, to smooth out the diurnal fluctuations in the steam flow, but even a reduction of 2 per cent in same would empty the reservoir, if the plant is to be kept under full load for 24 hours, which is practically the case during the

pumping season, as shown in the daily load curves Fig. 4. Maybe I d'd not understand this correctly and I should be thankful to have it explained.

Third: With an average load factor of 50 per cent the fixed charges on a hydroelectric plant must be quite high, and with the stated low rates for power it would be interesting to know, whether a large capacity steam plant to be operated during the irrigating season would not make a better financial showing than an additional hydroelectric plant with ten miles of conduit. This might be advantageously located in the Coalinga oil field region, only about 10 miles distant from Visalia, as it might prove more economical to ship current by wire than oil by rail or pipe line.

L. Jorgensen: In general the hydraulic conduit is the weakest link in power transmission for the reason that, from a financial standpoint, it cannot be installed in duplicate. Therefore, on systems with only one or two power plants it is most important to have this link well built. Tunnels are not the only safe conduit, but concrete pipes completely buried are in most cases just as safe, cost only half and require less grade, due to their better hydraulic shape. It is true that a flume costs only about half as much to build as a concrete conduit costs to install, but, if the depreciation, maintenance and interest on the investment are taken into consideration, their cost will be the same. Then the question of whether to use a wooden flume or a concrete conduit is simply a matter of whether the greater amount of money required to cover the first cost of the concrete conduit will balance against the additional safety connected with the use of a buried conduit. How tunnel compares in cost with either wooden flume or concrete conduit will depend upon how much of a short cut it makes. The first cost per linear foot may be four times that of a flume of the same carrying capacity, but a flume or concrete pipe line must follow the contour of the hillside, whereas a tunnel cuts through the hills.

Where the country is flat and otherwise adapted for ditch construction, ditches will be the cheapest, as maintenance cost is lower than for flumes, and depreciation is practically zero. Wooden stave pipes will accomplish the same as concrete pipes and have a lower first cost. If buried they are protected against rolling boulders, frost, etc., but their life is very short and repairs are difficult to make. Taking it all in all the concrete conduit does not seem to be as extensively used as all its good properties should warrant.

E. W. Paul: I would ask Mr. Hays if, on some of these circuits running to pumping plants, he has made any provision on the customers' premises to take care of the motor in case the current goes off the line, that is, as to voltage switches, and also how he even gets farmers to sign the contract described, with the conditions mentioned in his paper?

Ralph W. Pope: I am familiar with the territory where this plant is situated that has been developed for the raising of oranges. I was there twenty years ago when most of it was devoted to the production of wheat. At the time this plant started or a little earlier, the soil had deteriorated owing to continuous wheat cropping. I understand from the author that the soil was exhausted only about four or five inches down, so that orange culture is now pursued with great success. Referring to Mr. Henshaw's inquiries in regard to the pumping, I understand that pumps were formerly operated by windmills or gasoline engines, and that wells had already been dug, so that the question was not whether water could be got there, or not; because it had already been obtained.

There are certain tracts however where the water cannot be reached by digging or boring. The only value pertaining to such land is the possibility of selling it to eastern tenderfeet, which is another source of revenue not mentioned by the author.

In regard to the light construction of this plant, it must be remembered that at the time it was started, while having the water power, something like 7000 h.p., I believe that the question of a market was rather problematical, and ordinarily that is one of the most important questions to be considered in developing a water power plant. It was for this reason that the cheap construction was used in this particular instance. Those of you who are familiar with railroad construction throughout the country, know that in early days the construction was frequently of a very cheap character in comparison with what it is to-day. Railroads at that time were an experiment, but as the importance of proper construction developed, and rebuilding was undertaken it was found advisable to strive for permanency. This paper indicates that it is a long, slow process to develop an enterprise of this kind, but when it is permanently established it becomes an attractive investment, if you can find a territory where these conditions prevail. In Utah, I think they need something of this kind, as they have used up about all the water power that is available in that state.

Markham Cheever: Answering Mr. Pope's inquiry regarding the conditions in Utah, underground waters occur in large quantities in the fertile valleys of Utah Lake and the Jordan River, and artesian wells are numerous. However, this water is not used for irrigation to any great extent.

Utah Lake is one of the largest bodies of fresh water in the West and forms a natural reservoir from which the canals of the Jordan River Valley are supplied. As the lake level lowers during the summer, the outflow is maintained by means of large centrifugal pumps. Several projects involving the pumping of water to land lying at a considerable elevation above the lake are contemplated and one is now in operation. While hydroelectric power is used or proposed for all these pumping propositions, the load is not as satisfactory to the power pro-

ducer as that of the project described in the paper, on account of the much shorter irrigation season in Utah.

F. V. Henshaw: I would like to add one word, that this matter of underground water is a very essential thing to anybody contemplating going into an enterprise of this kind. I can say positively that in some parts of Colorado, the subject has been very thoroughly investigated and the water is not there. I would like to tell you where, but am afraid it would hurt the feelings of some "eastern capitalists."

A. J. Bowie Jr.: This load curve is different from any others I have seen in that there is no peak in the evening. This is of interest in matters of irrigation, since the value of the power which can be supplied, of course depends on the nature of the load curve and how the power is used. When the peak comes in the evening the power company can afford to supply power very much cheaper to the farmers who will shut down at that time. The load for irrigation differs from other types in that it is possible that suitable arrangements may be made to cut it off for a few hours a day without suffering serious inconvenience. This is particularly true where small reservoirs are used, reference to which has already been made, and the value of these reservoirs I consider of very great importance in the problem of irrigation. These reservoirs should hold about a day's supply for the farmer, who by that means is enabled to employ his water at such hours as are most advantageous. If his pumping station is small, he may use his entire supply in a few hours, instead of having to devote the entire day to the use of water. These reservoirs constructed of earth, are used in a great many parts of the country, and sometimes they are lined when the earth is unsuitable for holding of water. One form lining consists of coal tar, lime, and sand, spread on half an inch in thickness. I have also seen this lining applied where the reservoirs without it would not be able to hold water.

These reservoirs cut down very materially the size of a plant which it is required to install, as well as the corresponding additional investment and they avoid all night irrigation. The economic consideration of irrigation requires a suitable proportioning of the various items of expense which make up the cost of pumping, which may be segregated as (1) the cost of fuel or power, (2) the attendance and (3) the fixed charges, as well as the cost of applying the irrigation water to the land. The sum of these charges should be reduced to a minimum. In irrigating plants the depreciation is generally high. I think, allowing for all fixed charges, 20 per cent, would often be a low figure to cover interest and depreciation repairs and renewals. It is not unusual in countries where fuel and labor are cheap to find the fixed expenses exceeding the other two expenses. A small reservoir would avoid this and be a considerable saving in this way.

In Southern Texas the average depth of irrigation water used

annually was 2.7 feet for all crops, while for alfalfa it was 5.7 feet. The efficiency of most of the pumping plants in that country was exceedingly low. That would apply to any country where plants of a similar type were employed. The cost of pumping an acre foot of water one foot high was four cents, and as the power to raise an acre foot of water one foot high is equal to about one water kw. hour, this would amount to about 4 cents per water kw. hr. This is an average of course.

It may be of interest to you to know that we have quite a little irrigation in the Eastern states for truck gardens. The depth of water employed there depends on the source of supply and the cost of obtaining it, and varies from four to eight inches per year. Many farmers are using city water irrigating to an annual depth of about four inches. This costs for water about \$25 per acre per year, where as when pumped water is used, about twice the depth is used at the same cost per acre per year. The average increase in crop values per acre due to irrigation, and allowing for wet and dry years, is about \$200 per year over and above all expenses. In other words this is the average net profit of the farmer from irrigating. Of course that is large, but the crops raised per acre are of great value, in some cases going as high as \$1500 per acre per annum, so that it does not take very long even in a wet year to make a substantial gain.

W. A. Doble: I think Mr. Hays' excellent paper has been somewhat misunderstood with reference to the cost of this Mt. Whitney plant. We must bear in mind that that was one of the very earliest plants to be built, and was considered at that time the most thorough and best construction that could be done. It was considered that that was the best that could be done at that time. The cash was raised in advance and everything was paid for in cash, and it was put in practically at the lowest rate per horse power of any plant that could be built. The type of construction was not adopted as temporary, but simply because it was the best we knew about at that date. We may deal in generalities on the question of the hydraulic conduit. We cannot say that the flume or tunnel is cheaper or better. The Mt. Whitney No. 1 flume is 30,000 feet long, and a tunnel would have to be 20,000 feet long. The flume is not of large size, and therefore it can be put through at a comparatively small cost, and as the cost for the cross-section of the flume increases, the cost of its construction increases very rapidly. As a tunnel becomes larger its cost decreases very largely. We cannot generalize on those things; each case must be figured out for itself, so that I think a wrong impression is gained. The conditions that surround the Mt. Whitney plant are favorable for the long life of a flume or pole line. The average life of a flume in California is about ten years, and then its cost of maintenance becomes so very great that it is a serious tax. Then, again, we must consider the character of the country we are going through. If it is a country where the slopes are gradual, then it is all right

for flume construction. It is purely a case as to whether we shall adopt a flume, or a ditch, or a tunnel, and that depends upon the country, upon its size, and also as to whether a combination of the two shall be used, using a flume where it is more difficult, and then using an open ditch where it is more favorable. In southern California we have wooden flumes that are now being replaced with reinforced concrete flumes. I will close by saying that I think some of the members have gained a wrong impression of the Mt. Whitney Company. It was started in 1898, and that is ancient history now.

F. G. Baum: Mr. Hays gives some interesting data relative to the method of making power contracts for irrigation service, which should be of use to other companies in similar service. His remarks on the character of the contracts to meet the needs, and also his remarks on the character of the construction to give the service, illustrate the principle that "local conditions" must be taken into account whenever one goes into new problems or attempts to criticize the work of others.

To say that timber face dams, wooden flumes, simply equipped power houses, wooden poles and simple substations are always wrong, and that concrete dams, elaborately equipped power houses, steel towers and elaborate substations are right, only emphasizes the fact that the man making such statements does not take into consideration all the facts. Very often we do not build more permanently for the very simple reason that the money is not available. One builds a house generally to suit his needs and his pocketbook, and a man is not a fool for building a frame house instead of a brick house. We have ferry boats to go over the water before we have tunnels to go under. We crawl before we walk.

As I stated in a paper "Some Power Transmission Economics" at the annual meeting of 1907: "In designing power transmission systems, it is always well to bear in mind that the ultimate development of the art and of the country has not yet been reached.

"In the early days of railroading, the roads and equipment were not of the present trunk-line standard. Light rails, engines and cars, and unfenced right-of-way, and unballasted roadway sufficed. To construct, at that time, up to the present standard would have meant bankruptcy. Even now the manager or engineer, who would build his branch lines of the same standard as his trunk lines, would invite a receiver to take charge of the road.

"The same conditions hold true for power plants and transmission lines. The wise manager or engineer builds to meet existing conditions, looking into the future as far as he can. He cannot afford to build duplicate plants and lines for every case, nor build all his lines on private rights-of-way with steel towers and other refinements and safeguards. He cannot afford to build a duplicate transmission line, at an additional interest

cost of \$5,000 per year, when the probability of an interruption, which will cause a loss of revenue of \$500 per year to a consumer, is extremely remote.

"It may not be as difficult to determine the proper power station and line to build when unlimited capital and ideal power conditions exist as when there is restricted capital, limited revenue, and low-priced power at the consumer's station. Although in the latter case the amount of money to be expended may be much less than in the former, even more thought is demanded of the engineer; for in the former case, having ample resources, he builds as best he can, while in the latter he must be a judge of conditions and see far ahead, in order that the work which he builds may earn money and at the same time be capable of extension on some plan to meet the growing needs of the country and business.

"On the hydraulic construction and also on the power house and substation installation and construction, the engineer is required to devise something that will pay the largest net income in a given number of years. Sometimes he is called upon to make installations on the assumption that the plant is to be abandoned in a few years. Of course, the engineer will be criticized if he puts in a plant to meet present or apparent future needs and, due to some change in the industry or development of the country, the plant must be remodeled later. But it is the business of the engineer to solve his problems as he sees them."

Much more might be said along the same line to illustrate that construction which may be right for the New York Central R.R., or in the city of New York, may not be right for the Tonapah & Tidewater, or the town of Tonapah.

Engineers must fight the tendency to "build monuments" to themselves. Many of these "monuments" mark the death of a corporation."

Mr. Hays: As to the stream flow and the different reservoirs at power house No. 1, no provision was made for a regulating reservoir when the plant was first constructed, but afterwards, as the load was built up, we found that we had a slight peak; that was back about five years ago, before these curves showed, and we built a little reservoir there with the idea of carrying over the peak load, and as small as that was, it served its purpose very well. On the No. 2 plant, I don't know why that reservoir was put there, it was probably just put there for good measure, and probably because it was a good place for one.

On the Tule River plant we took the matter up carefully as to what size reservoir we should build. We compared the daily load curves with the daily curves of discharge of the river during low water periods and while the stream flow varied to quite an extent during the day it happens to coincide with the load curve. For instance at the height of the peak in the morning the stream flow was greatest and fell off in the evening with the load,

consequently very little if any reservoir capacity was required. The reservoir was therefore built to take care of the fluctuation of the river assuming that the most unfavorable conditions were encountered or that the low water flow would occur at the time of peak load. Also the reservoir has capacity to run the plant until the steam auxiliary may be brought into commission, in case of accident to the flume.

As to the permanency of construction, of course in a case of this kind we are dealing with simple units starting from the motors right up to the power house. The average size motor on the system is a $7\frac{1}{2}$ h.p.—you might say that we were doing a peddling business. The old No. 1 flume that Mr. Doble spoke of was put in for an economical reason, it was far cheaper to put in the flume than a ditch or a tunnel. The flume has been in there for twelve years, and, apparently, with the exception of being water-stained, it is still in good shape. It looks as though it had about ten years more life left in it, and there is no maintenance to speak of required on it.

On the No. 2 plant we have put in a concrete ditch. On Tule River plant we have run in a concrete ditch where the slopes would permit. We also, in that plant, have gone further than the ordinary concrete ditch and do not rely at all on the concrete or on the strength of the bank, the high water level in the ditch being just six inches above the ordinary surface of the slope of the hill. Those improvements that we have put in will eventually double the capacity of the plant, when this ditch and bank have settled down. Also, there are two very long stretches of flume on the Tule River, which some day can be cut out by putting in a tunnel. That flume is of pine, not of redwood, and probably will not last as long as the old No. 1 flume, which has been in use for the last fifteen years.

I don't think that economy could be said to figure in on any one thing with the exception of the main power line and the distributing system. They are all light stuff, all light poles, and they last very well in that country. As to the steam plants taking care of the peak loads, I believe that when the system gets a little larger by increasing the capacity of the present hydraulic plant and in carrying over the peak load by steam, that it will work out all right. Roughly, I have figures on it when the plant gets about twice its present size. We have always considered the present steam plant, simply as an auxiliary. That is a pretty heavy investment to use for that purpose, but as mentioned in the last part of the paper, the company has very much of a responsibility. We have a very large community depending upon a comparatively small power system, and if some accident should put a generating station out of business for a year, it would seriously interfere with a crop. You have to keep some auxiliary ready for all emergencies. Little interruptions do not make any difference. If the Pacific Gas and Electric Company should have its lights go out for fifteen min-

utes between six and seven o'clock at night, it would be a serious matter. For ours to go out between six and seven at night about half of one per cent of the consumers would pay their bill next month and make a "kick" about it.

As to the protection of the motors: That has been one of the things we have been trying very hard to arrange for, and the only practicable apparatus we can furnish is just a straight circuit-breaker, so that when the current goes off, the motor stops, and when the power comes on again, it will trip the circuit-breaker. The average farmer objects to even putting that protection on. All he wants is a fuse. In fact, last year some of our consumers held an indignation meeting because they understood we were obliging them to put on circuit breakers, and they said they would not do it. They held a meeting, and decided that we were trying to get \$36 more out of them and they would not stand for it. In fact, we had more trouble with them about that, than we have with them about the contracts. We get them to sign the contracts, sometimes they object, but the contract is absolutely fair. We have to give them a cheap rate, but we work on practically a cash basis. The penalty of one per cent per month provided in the contract is no joke. We actually enforce it, and yet it is not an unusual thing for a man to wait until the end of the year before he pays his bill. Some consumers prefer to pay that one per cent per month interest, and so we allow them to wait until the end of the year.

In operating a pump station I don't know of a single instance in that section where labor costs have been counted. A man generally does the work himself, oils up his pump and looks at his motor about twice a day, goes down into the field, and if the water stops he goes back and finds out what is the matter.

As to the secretary's reference to the underground water, I will say that I do not know of any cases in that section where they have dug for water and did not find it. Some of the growers tried to go up too far into the mountains and there were some wells there that were abandoned after they struck rock, bed rock and granite, and some of them, I presume, never would have reached water.

We have something better for the eastern tenderfoot than the dry lands. We have the "white ash" land, or that which is generally known as alkali land down there, and that sells very well to easterners, and there is more profit in it.