opposed to the granting of any water rights whatever that would interfere with its plans for increased irrigation facilities. In the eastern part of Peru there is such an abundance of water that this restriction does not obtain, but on the seaboard it is necessary either to utilize the higher levels of the streams (up in the mountains), or to have recourse to partial and successive developments so as not to interfere with irrigation. For the specific case of Arequipa, the latter plan is the most practical.

By lowering the location of the present plant about 400 metres, it would be a simple matter to increase the head from the 26 metres now available, to at least 100 metres. This would in no wise prejudice irrigation, as there are no lands whatever under cultivation between the present and the proposed locations of the plant.

By lengthening the present flume or ditch, a force of 4,000 horse-power could be developed, while by building a new flume of sufficient capacity to carry the 6 cubic metres of which the Chile River disposes, a force of 6,000 horse-power could be obtained.

Electrify the Railroads.

With such a supply of electrical energy available, the electrification of the railroads of southern Peru would follow in due course, either totally or partially, creating a large market for power.

The Peruvian Southern Railroad operates 359 kilometres of road over an average grade of 1.3 per cent., between Mollendo, which is at sea level, and Crucero Alto, the highest point on the line, at an altitude of 4.840 metres.

Allowing 33⅓ per cent. for losses from all sources, which is excessive, the remaining 4,000 horse-power available would suffice to move five trains of 70 tons each at a speed of 36 kilometres per hour, which is far in excess of present or ultimate traffic demands on the road, especially if tri-phase traction operation is adopted, when the returning cars on the down grade, instead of consuming, would on the contrary generate additional current, the motors being converted into generators. The total mileage of the road is not beyond the limit of economical electrical operation over high transmission lines, at the present day.

The next and by far the most important source of water-power supply of Peru, points out the hardy pioneer, is Lake Titicaca, lying 3,800 metres above the level of the sea, with a surface area of 6,600 square kilometres, and an average depth of 20 metres.

Many Rivers Empty Into Lake.

Lake Titicaca, as is well-known, is an isolated basin into which a great number of rivers empty. The outlet of this basin is the River Desaguadero, which discharges its waters into Pampa Aullagas, where they are lost through evaporation and filtration. There is a popular belief that a subterranean stream continues and discharges into the sea, but scientific investigations have failed to substantiate the theory and it appears certain that this water is absorbed only by evaporation and filtration. The fact remains however, that the Desaguadero River before entering the Pampa Aullagas carries a volume of 100 cubic metres of water per second, whereas the stream that serves as outlet to this lake has a volume of only 1 cubic metre per second. It is therefore evident that the greater part of the waters of the affluents of Lake Titicaca are lost through evaporation and filtration between the two lakes and the Desaguadero River.

The proportion of this loss due to evaporation returns in a measure to the drainage basin of Lake Titicaca in the form of rain, contributing in part only to the cycle here outlined.

Therefore, the project hereafter suggested contemplates exclusively the utilization of the water actually wasted by filtration in Pampa Aullagas.

Water to Fall Over Pacific Slope.

For various reasons, and especially for the purpose of utilizing this water for irrigation after leaving the turbines, it is desirable to have this water fall over the Pacific slope. Lake Titicaca lies in a hollow, surrounded on all sides by an unbroken ridge of mountains, ranging from 250 to 800 metres in height, presenting a formidable engineering problem which can be overcome by only two solutions; either tunnelling through the mountain, or pumping the water up and over the lowest practicable eminence.

The distance from Lake Titicaca to the Pacific Ocean, as the crow flies, is 250 kilometres.

According to surveys, the shortest practicable tunnel that could be bored through this natural barrier to the nearest valley, would be between 35 and 40 miles long; this, while entailing an enormous cost, would greatly shorten the transmission line.

As regards the alternative plan of pumping the water over the side of the mountains, it should be called to mind that the highest point on the ridge immediately encircling the lake is Crucero Alto, at an elevation of 4,600 metres, or about 800 metres above the level of the lake. In the event of an actual undertaking of such an enterprise, a much lower point would of course be determined upon, after proper surveys; but for the purpose of demonstrating its feasibility, Crucero Alto will be selected as the peak to which the water must be raised, and furthermore, the pipe line will be assumed to follow the tracks of the Peruvian Southern Railroad (a very much longer and more circuitous route than would be taken in practice), a total distance of 524 kilometres.

Some Big Figures.

To raise 100 cubic metres of water one metre in one second requires 1,000 horse-power with good pumps. The difference in levels between the surface of the lake and Crucero Alto being 800 metres, a force of 1,900 x 800 = 1,520,000 horse-power would be necessary.

At first sight this figure appears appalling, but it will be shown hereafter that the available supply of power for the pumping station would be far in excess of this amount.

100 cubic metres of water under a head of 4,600 metres represent a theoretical force of 6,133,333 horse-power which, after deducting 1,520,000 horse-power consumed at the pumping station, would still have a theoretical supply of 4,613,333 horse-power to dispose of.

Assuming the penstock to be built of a number of pipes, each 1 metre in diameter and carrying a volume of 628.3 litres of water at a velocity of 0.8 metres per second, loss of head may be estimated at 1 metre per kilometre, or 524 metres for the entire line, equal to 698,666 horse-power to be deducted.

Further, allowing 1,914,667 horse-power for losses from all sources, in the turbines, generators, etc. (which is extremely liberal), a net surplus of 2,000,000 horse-power of electrical energy would be left available for sale.

The plan above provides for the driving of the pumps by the electrical energy generated by their own initial action, but it must of course be understood that steam is contemplated as the original motive power at the pumping station. For example, a pumping station would first have to be installed on the edge of Lake Titicaca, at a suitable point such as Puno, driven by steam, with a capacity sufficient to force 1 cubic metre per second to a height of 800 metres. Such a pump would consume 1,520 horse-power to perform the work.

Thirty-five Horse-power Thousand.

The water would be pumped into a reservoir at Crucero Alto, from which it would fall by gravity to sea level, where it would develop, as above shown, an actual net force of 35,000 horse-power of electrical energy, or more than double the power required to drive the pump at Titicaca. After supplying this power to the first pump, there would be a reserve force of 20,000 horse-power left, which could be used to drive a second pump, and so on successively, until, with adequate capacity in the Crucero Alto reservoir, one hundred pumps could be kept in automatic operation, delivering a net total of 35,000 — 15,000 x 100 = 2,000,000 horse-power, as above demonstrated.

The market for this supply of power would be in its application to the electrification of present steam roads and the operation of new electric properties, mining and agricultural industries, public and private lighting, the manufacture of carbide calcium at the coal mines, the operation of overhead conveying cables which are in general use in Peru, and for heating, household, and general power purposes.