THE 2400-VOLT RAILWAY OF THE BETHLEHEM-CHILE IRON MINES COMPANY

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The work to be done in developing the rich iron mines at Tofo, Chile, includes the construction of a very difficult line of railway which is to operate at 2400 volts direct-current, the building of a steam power station and transmission line, the installation of electric shovels and crushers, and the building of a settlement for the officers and operators of the company. The author gives a short outline of the work contemplated and cites some of the local conditions which make this undertaking one of particular difficulty.—Editor.

One often notices in technical papers and popular magazines articles describing the wonderful mineral resources of South America, especially large deposits of iron and copper ores, but few realize how rapidly and on what a large scale these resources are being developed and where the products find a market. A remarkable deposit of iron ore is found at Tofo, Chile, where the Bethlehem-Chile Iron Mines Company is preparing to mine this ore with the aid of electric power and to ship it to the United States for use in the blast furnaces at South Bethlehem, Pa.

These mines occupy the summit of two hills, approximately 2000 ft. above sea level and about four miles in an air line from the port of Cruz Grande. The remarkable feature of these mines is that there are great quantities of ore in sight and it is nearly pure iron (67 per cent Fe.). With the opening of the Panama Canal to commerce this ore can be mined and shipped by that route from Chile to New York and thence to South Bethlehem, Pa.

An electric railway operating at 2400 volts is now being built to develop these mines. In addition to this electric railway the development will include a steam-power station and high tension transmission lines, from the port of Cruz Grande to Tofo, and the installation of electric shovels, crushers and other machinery for mining operations at Tofo. Ore pockets and vessel loading piers will be constructed at Cruz Grande. It requires also the building of residences for officials and establishing ample water supply and fire protection as well as the provision of an electric lighting system for the villages, piers, etc.

At present a certain tonnage of ore is mined by steam drilling and transported to the coast over a telpherage system which consists of a string of ore buckets suspended from a steel cable supported on steel towers and operated by the weight of the loaded buckets descending, which furnish power for taking up the empties. This system is started by a gas engine, but when once started it requires no external force to keep it running, in fact, part of the energy is dissipated in operating a large fan which is used for governing the speed. Probably one of the chief reasons for adopting this system was on account of the small amount of power required to operate it.

It was essential that means be provided for saving water and fuel, in other words, power. Obviously, the power taken by the empty trains ascending the grades, if supplied by loaded trains descending, would represent a saving which could not be effected by minor economies of fuel. This feature in the railway electrification, therefore, received a great deal of attention both from the standpoint of saving power and on account of other practical operating advantages.

The railroad from the mines to the piers is approximately 15 miles long with an average grade for nearly the entire distance of three per cent. This is also the maximum grade. Its alignment is far from straight, as may be seen from the fact that in an air line the mines are only four miles from the coast, whereas the railroad reaches the same height only after traversing 15 miles.

In the operation of heavy grade sections of steam railroads great difficulty has been found in getting rid of the heat from brake-shoes and wheels, which is another argument in favor of electric braking on the locomotives. In the study of this problem it was shown that regenerative braking could be accomplished successfully on a high voltage direct current system, that is, the motors under the locomotive are made to act as generators and return energy to the trolley to be used by another locomotive ascending, or back to the power house where it would help supply the demands of the mines.

These locomotives will weigh 110 tons on drivers and will be equipped with four 300-h.p., 1200/2400-volt motors operated two connected permanently in series on 2400 volts. The initial installation will consist of three of these locomotives, each having a capacity to haul a 450-ton train up grade at 10½ m.p.h. and exerting the same braking effort when regenerating at 12 m.p.h.

In case the locomotives are operating with the maximum train weights down grade a portion of the braking will be done with air brakes, and when stopping air brakes will be used alone.

The trolley will be of 4/0 grooved copper wire, catenary suspended from a steel messenger supported by a mixture of bracket and cross span construction on wood poles. These poles will be of cedar and will be shipped from the United States, as Chile grows no timber suitable for this purpose. A duplicate 22,000-volt high tension transmission line will in general follow the trolley and will be carried on the same poles when possible. In places, however, it will leave the railroad right of way for a more direct route to the mines. These transmission lines will supply power for the operation of crushers, electric shovels, pneumatic tools and machine shops, as well as for pumping water and other sundry purposes.

The mining of this ore will be accomplished by blasting the ore exactly as in modern rock quarries, and then by means of electric shovels it will be loaded onto side-dump cars, when it will be hauled a short distance to the crusher plant and crushed to a size suitable for use in blast furnaces. The crushed ore will fall by gravity into bins ready for loading into hopper cars; it will then be hauled to the vessel loading piers and dumped into ore pockets. From here it is loaded by gravity into 17,000-ton steel vessels specially constructed for this purpose and shipped to unloading piers in New Jersey, and there loaded onto cars for South Bethlehem, Pa., where it is ready for the blast furnaces. The transportation of the ore is, therefore, a big item of its cost and every facility has been provided to save the expense of handling it.

In the power house oil-fired boilers are to be used which will permit of an easy control of the heat with every fluctuation of load, and because of absence of dirt the usual partition between the generator room and the boiler room will be omitted so that the operators will be able to anticipate changes in load in time to make proper adjustments. The oil is received in tank vessels and pumped to an oil storage tank above the power station. From the main reservoir it runs by gravity to the auxiliary reservoir near the station and is fed to the burners by means of a small pump. The boilers will be set high so that grates may be installed if there is any advantage to be obtained from the use of coal.

One of the interesting features of this installation is the ingenious method employed for evaporating boiler "make-up" water from sea water. This is done by an evaporating condenser through which is "by-passed" a part of the exhaust steam from the turbines. By adjusting the difference in the vacuum between the main and the evaporating condensers the amount of evaporation can easily be governed without affecting the economy of the steam turbines appreciably.

The generating room contains two 3500-kw. three-phase, 60-cycle, 2300-volt Curtis G-E steam turbines with direct-connected exciters for supplying power to the railroad and the mines; two 300-kw. three-phase, 60-cycle, 600-volt turbines for operating motor-driven auxiliaries, fire pumps, etc., and at night, lights for the piers, villages and mines when the main turbines are shut down. To accomplish this result there is installed a small bank of step-up transformers so that the high tension lines may be energized at minimum loss. This arrangement avoids considerable complication in the switchboard wiring and avoids providing steam-driven auxiliaries with complicated steam and water piping.

Power for the operation of the mines and crusher plant is stepped up by means of two banks of transformers, each bank consisting of three 667-kv-a., 60-cycle, 22,000/2300-volt oil-cooled transformers. At the mines the voltage is stepped down again to 2300 volts for local distribution. Power for the operation of the railroad is taken through two 1000-kw., three-unit motor-generator sets, each consisting of one 1400-kv-a., 0.8-p-f. three-phase, 60-cycle, 2300-volt synchronous motor-generator set direct-connected to two 500-kw., 1200/2400-volt direct-current generators, designed to operate two in series on 2400 volts. These sets have direct-connected exciters on each end for exciting the synchronous motor and d-c. generators. Space has been left in the design of the building for future boilers, main turbines and motor-generator sets when required.

The power station building will be located on solid rock foundations and a type of construction employed which is particularly adapted to resist earthquake shocks, which are frequent and sometimes violent and followed by tidal waves. It will, therefore, be located back from the water's edge, on high land reasonably safe from these disturbances. A pump house of very sturdy construction will be erected at the water's edge to supply circulating water to the condensers and for fire protection for the village and piers.

Nearly all the sources of fresh water supply are located in the valley behind the mines and it requires pumping to the mine level for use at the mines. The excess is stored in reservoirs between the mines and Cruz Grande for such purposes for which it is suitable and also to relieve the pressure on the pipes at Cruz Grande. At the present time a great deal of this work has been completed and a temporary pumping and lighting plant is installed near one of these springs and supplies water for the mines and lights for the villages.

ELECTRO-CULTURE: A RESUMÉ OF THE LITERATURE

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The literature published on electro-culture is extensive but scattered. The writer has made an excellent review of this published matter, dividing the subject according to the different methods used to stimulate plant life by electricity. The progress, or lack of progress, made by the application of each method, is discussed, and the conclusion is reached that these investigations, on the whole, have been too cursory. A valuable list of references is also given.—Editor.

The scientific literature of the last ten years has contained frequent references to the art of increasing plant growth and yield by the application of electric stimuli of certain kinds, an art most commonly designated as electro-culture. The material given, however, represents very little experimental work in proportion to its volume, consisting in the main of more or less complete historical reviews concluded by a few paragraphs describing some recent investigation. The effect upon a reader desiring to become acquainted with the work done within a reasonable length of time is irritating, to say the least. In view of the growing interest in intensive methods of agriculture, and also in methods of filling in the valleys in the load curves of central stations, there is reason to expect a much more exhaustive investigation of this subject in the not remote future. For this reason it has seemed desirable to collect the facts from the scattered sources, and attempt to arrange them in a form more convenient for use, that is, from the point of view of the invader of the province rather than the historian.

It has been found that the experiments of the past fall naturally into five classes, differing principally in the method of application of electrical energy. These methods are:

I. Illumination by electric light.

II. Conduction of atmospheric electricity from an elevated collector to an electrode in the soil, or to discharge points above the plants.

III. Constituting the soil the electrolyte of a voltaic cell by burying in it two plates of dissimilar metal connected by a conductor.

IV. Passing current from an external source through the soil between electrodes buried therein.

V. Production of a silent or glow discharge through the air from overhead antennae to the soil.

These methods will be taken up in the order given, which is approximately that of their importance.

METHOD I

Illumination by electric light.

There seems to have been relatively little work done upon the effect of illuminating plants by artificial or electric light. In 1861 "Hervé" Mangon found that electric light influences the formation of chlorophyl in a way similar to that of sunlight. That the absorption and assimilation of carbon dioxide occurred as usual under the electric arc was shown by Prèllieux eight years later.[1]

In 1880 Wilhelm Siemens confirmed these observations, but found that under certain conditions injurious effects were obtained, and hence he used an opalescent glass shade over the light.

These facts were further confirmed by Schraier in 1881, and by Bailey, Cornell University, in 1891. Bonnier in 1892, and Couchet in 1901, studied the structure alteration in plants and the leaf growth in relation to the electric light.

Since 1891 this line of attack has been neglected, probably because of the attention attracted by the work of Lemström, and the success of his method.

Dorsey, however, in 1914, mentions the treatment of hothouse radishes and lettuce for three hours each day beginning at sunset,