tightly closed, having neither grate-bars nor ash-pit. Into the front of this chamber, and on the same level, there enter two short horizontal pipes, or *tuyeres*, about two feet apart. The outer ends of these *tuyeres* are connected to a main air blast-pipe, which is kept filled with air under a slight pressure by means of an ordinary blower. Simple valves permit the ready and accurate adjustment of the amount of air passing through the *tuyeres* into the combustion-chamber. Between and slightly above these *tuyeres* is a small rectangular hopper, into the top of which the finely pulverized coal is fed by screw-conveyers. The coal is fed out of the hopper by means of an ordinary screw of about two inches diameter, which passes horizontally through the lower portion of the hopper, issuing from its opposite sides through holes just large enough to loosely fit the outside of the screw. The pulverized coal lodges between the threads of the screw, and, on revolving the latter, the coal is fed out through the side of the hopper. One end of the screw is right-handed, and the other is left-handed, though both ends are of the same pitch. It follows, therefore, that the coal will be fed out of both ends of the hopper at exactly the same rate, this rate depending on the speed of revolution of the screw. The coal is kept from packing or becoming solidly wedged in the hopper by means of an agitator kept in motion immediately above the feeding-screw. On issuing from the hopper, the pulverized coal drops into the *tuyeres* directly below, and is carried to the combustion-chamber by the blast of air passing through the *tuyeres*, becoming intimately mixed with this air at the same time. Only enough air is admitted to secure complete combustion, thus avoiding the great loss due to the excessive amount of air necessarily admitted when burning lump-coal on an ordinary grate. The feeding-screw is operated by gearing driven from a convenient line of shafting, such arrangements being made as will secure a readily and accurately adjustable motion of the screw, and hence a readily and accurately adjustable feed of the fuel.

As the relative as well as absolute amounts of coal and of air can thus be adjusted at will, and with any desired degree of precision, it follows that the character and intensity of the flame are completely under control. The ability to thus produce, and maintain for any desired length of time, a flame of any desired intensity, and either reducing, neutral, or oxidizing in character, carries with it, for metallurgical purposes, many advantages too well known to need more than a passing allusion.

In the Chester Rolling Mills the apparatus was attached directly to the combustion-chamber of one of their regular puddling-furnaces, though greater economy would probably have been obtained by the use of a special form of combustion-chamber devised for this purpose. The coal was the same as that used for all the other puddling-furnaces, except that it was pulverized. No conveyers were fitted to feed coal into the hopper, the coal being furnished in bags of one hundred pounds each, which were emptied into the hopper as required. As thus applied, this process realized a very large measure of success. The furnace was heated more rapidly after charging than the other furnaces, which were being worked in the ordinary manner, though with the same iron. More heats were obtained per day with the new process, less fuel was consumed per ton of iron produced, less iron was wasted in puddling, and the iron produced proved to be of slightly superior quality. There was no smoke, and the ashes was carried out of the top of the chimney in the form of fine dust, invisible from the ground. While charging the furnace, the supply of both air and fuel was completely stopped, thus preventing waste, and enabling the men to work more quickly. In considering the superior economy of this process, it must be borne in mind that the actual economy in the production of heat from any given fuel does not represent the total gain; for by this process very cheap and otherwise comparatively useless slack coal and coal-dust will answer nearly all purposes, thus presenting another material advantage.

It is of course impossible to give exact figures, except from observations extending over a much longer period of time than was at my disposal at Chester. There can, however, be no question that the McAuley process effects a considerable and substantial gain in economy of fuel-consumption. There remains simply the determination of the exact amount of this gain by means of accurately conducted experiments by scientific and practical experts.

The process has very recently been applied to the puddling-furnaces of the Warren Iron and Steel Company at Warren, O., and the success obtained seems to have been very great. A report of the trial there given this process has just reached me, and reads as follows: —

"The results of the trial just completed at the works of the Warren Iron and Steel Company, Warren, O., with the McAuley pulverized fuel system, are remarkable. The trials covered forty-six on two of the puddling-furnaces. The furnaces were charged with 23,000 pounds of iron during the trial. The amount of pulverized coal used was 12,260 pounds (a little over six tons). The cost of this fuel was $5.43. The amount of iron drawn from the furnaces was 24,029 pounds, an excess of 1,029 pounds over the amount put in the furnaces originally. This is what the McAuley system accomplished.

"By the old process, now in use, during the same heats, the amount of coal required was 36,920 pounds (over eighteen tons), the cost of which was $16.50: in other words, the McAuley process saved nearly 75 per cent of fuel. The McAuley process increased the amount of iron 5½ per cent; that is, there was 5½ per cent more iron taken out by the new process than was charged. This gain is worth $15.45: in other words, the gain in iron alone pays for nearly three times as much coal as is required by the McAuley process. The iron-men who witnessed the trials were astonished at the remarkable results. The iron gained by the McAuley process comes from the 'fix' which is used to protect the pan and sides from the intense heat, and also from the cinder, containing 50 per cent of iron, which is put in the furnaces to flux the iron. By the old process this is all lost, and in addition there is generally over 5 per cent of waste. This means practically an actual gain of 10 per cent of iron by the new system."

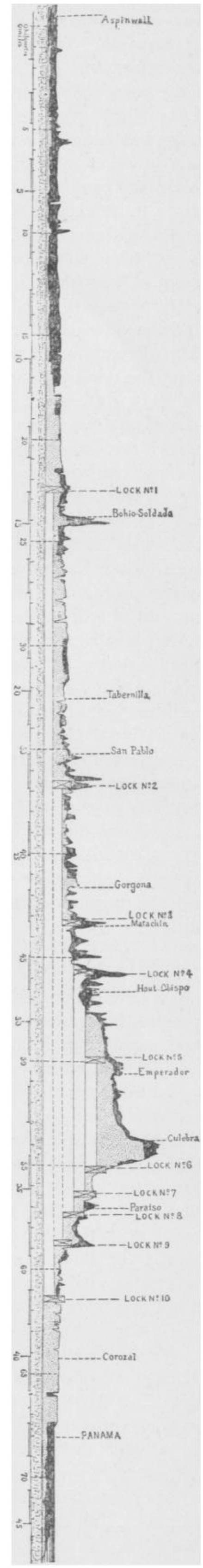
The puddling process makes specially severe demands on any such automatic fuel-feeder; and hence even better results may be expected from the application of the new process to steam-boilers, both land and marine. It should prove especially valuable in marine boilers; for not only would the required speed be developed at less expense, but less coal would have to be carried for any given trip, and the space and weight so gained would, of course, be available for carrying paying freight.

Without going into any further details, it may be broadly stated that there are very few cases in which fuel is consumed in large quantities, where it could not be burned more advantageously in the pulverized form; and, as there can be no question that the McAuley economizer is the best apparatus yet invented for this purpose, it seems as though it were destined to work a great revolution in the manner and economy of consumption of fuel.

In conclusion, it may be of interest to state that the coal is pulverized for this process by means of the Cyclone pulverizer, the principle of which is fairly indicated by its name. Within a closed chamber a pair of wheels resembling three-bladed screw-propellers revolve very near each other at a great velocity, but in opposite directions. Two powerful currents of air in opposite directions are thus generated, their joint effect being to produce a miniature whirlwind within the chamber. Into the vortex of this enclosed cyclone the coal is regularly dropped, and is rapidly ground into the finest powder by the mutual attrition of its particles. There is no grinding or pulverizing by the direct action of any of the metal parts of the machine, so that the machine does a great deal of work with extremely little wear. X.

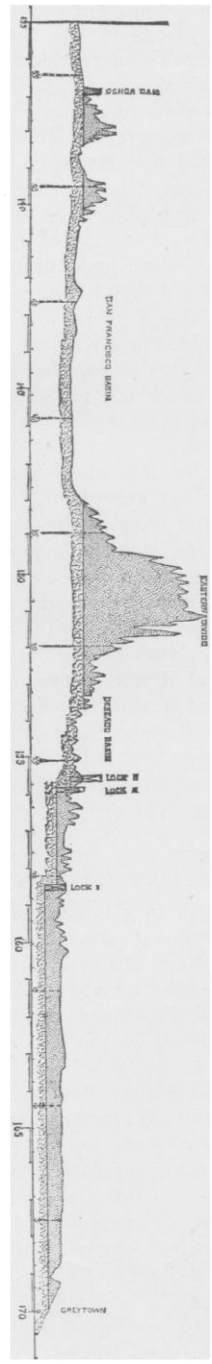
PROFILES OF THE NICARAGUA AND PANAMA CANALS.

THE failure of the Panama Canal Company makes the uninterrupted continuance of work on the canal very doubtful, and thus the chances of the Nicaragua Canal being the first to be completed have materially increased. The profiles on p. 323 show a comparative statement of the amount of excavating to be done in both canals; and it will be seen at a single glance, that, even considering the amount of work already accomplished at Panama, the Nicaragua route is by far the less difficult. The profiles do not show the works necessary for protecting the canal, such as dams

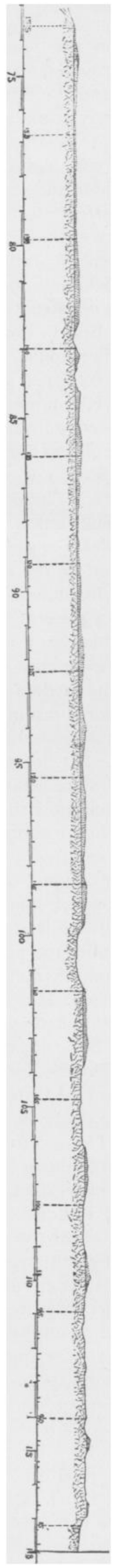


PROFILE OF THE PANAMA CANAL.

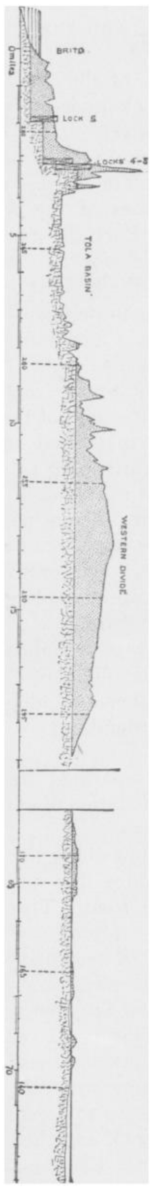
Black indicates work executed ; stipple, work to be executed to complete a lock-canal ; white, additional work to be executed to complete a sea-level canal.



Eastern Portion : from Greytown to the Dam of Ochoa.



Central Portion : from the Dam of Ochoa to Lake Nicaragua ; Bed of San Juan River.



Western Portion : from Lake Nicaragua to Brito.

PROFILE OF THE NICARAGUA CANAL (LOCATION OF 1888).

Stipple indicates amount of work to be executed to complete the canal.

and digging new canals for deviating rivers, etc., but these works are far more formidable in Panama than on the Isthmus of Nicaragua. The control of the Chagres River has been one of the most serious obstacles to successfully carrying on the work at Panama. On the route selected for the Nicaragua Canal by the surveying party of 1885, obstacles of a similar kind would have been encountered in the basin of the Rio Grande between Lake Nicaragua and Brito; but in the new plan of 1888 this difficulty has been overcome by damming up the river, and transforming its valley into an artificial lake, the Tola basin.

On the profile of the Panama Canal may be seen both the volumes to be excavated for the purpose of establishing a lock-canal and a sea-level canal. The number of locks necessary for the former is ten, while the plan of the Nicaragua Canal contemplates only six locks. A single glance shows that by far the greater amount of work necessary to complete a sea-level canal remains to be done, and that comparatively little has been accomplished in the most difficult sections of the canal. While it seems impossible to complete the deep Culebra cut on account of the movements of the soil, no such difficulties are anticipated in the short deep cut of the Nicaragua Canal crossing the eastern divide. Careful borings have shown the soundness of the rock.

If we consider that the Nicaragua Canal Company is just starting its work, while the Panama Canal Company is burdened with an enormous debt; that the amount of work left to be done is smaller in Nicaragua than in Panama, — we must regard the prospects of the former as very encouraging.

The profile of the Panama Canal shows, on the other hand, the amount of work done as compared to that left unfinished. Much money has been expended; and the interests at stake are so powerful, that we do not believe the work will be dropped, but will be pursued in some way or other. A decrease of the working force seems to be, however, at present unavoidable, and this will relieve the Nicaragua Canal Company of another difficulty, the scarcity of workingmen in these tropical regions. If the work on the latter is undertaken without unnecessary delay, and if it is continued as carefully as the preliminary surveys warrant it will be, we expect to see it completed at an early day. The Panama Canal, even if opened at a later day, will have to contend against an established route, run at smaller expense than its own, as the capital invested and the number of locks, which cause increased expense, will be smaller.

THE SPRAGUE ELECTRIC ROAD AT BOSTON.

WE take pleasure in presenting our readers in this issue of our paper with a general view of the new electric street-railway between Boston and Brookline, installed by the Sprague Electric Railway and Motor Company of New York. There have been several trial trips made over this railway already, to test the apparatus, which has been found to be perfect, and the road will be put into commercial operation in a few days.

The West End Street Railway of Boston, of which this road is a part, is the largest street-railway in the world. It extends over 212 miles of track, using 1,700 cars and more than 9,000 horses. The president of the West End Street Railway Company, Mr. Henry M. Whitney of Boston, is universally recognized as being one of the most enterprising and successful street-railway men in the country, and, aided by an efficient corps of assistants, has succeeded in giving Boston since his administration the most efficient street-railway service which ever existed in that city.

Before deciding upon any electric system to be adopted upon the West End Road, President Whitney, accompanied by members of the board of directors and managers, visited all the principal electric railways in the country operated upon the various systems, including visits upon three different occasions to Richmond, Va., to inspect the famous electric road in operation there upon the Sprague system. After a most careful examination of all these different roads, the contract for equipping the West End Road was awarded by the board of directors to the Sprague Electric Railway and Motor Company of New York.

This system of electric railway called for in this contract is wide and comprehensive. The main line from Boston westward, beginning at Park Square, will run down Boylston Street bridge, and then down Chester Park to Beacon Street. It will then proceed over the Beacon Street extension to the Chestnut Hill Reservoir, and to Allston, and Oak Square, Brighton. From the East Park gate, over the new boulevard to the Chestnut Hill Reservoir and Brighton, the Sprague overhead system will be adopted; in the more crowded streets of the city the Bentley-Knight conduit will be used; and the Sprague cars will run over the whole system.

The power-station from which the electric current is distributed to the line is situated on Braintree Street, Allston, near the Boston and Albany Railroad, and also at the edge of the water, thus giving both water and rail facilities for fuel. This building, which is the most perfect electric plant of its kind in the country, is situated very nearly equidistant from the extremities, and is therefore literally a central station. The station, with the adjoining car-house, is of brick, and completely fire-proof.

In its construction it was the aim of the West End Company to get the best in every detail. The chimney-stack is 100 feet high. The boiler-house, which is both convenient and commodious, is at present equipped with three horizontal tubular boilers, furnished by the Jarvis Engineering Company. The engine-room contains two high-speed automatic cut-off engines of the Armington & Sims pattern, of 200 horse-power each. Each drives two powerful dynamos of 80,000 watts each, and wound for a maximum pressure of 500 volts. These dynamos are of the highest efficiency and simplest construction, and, if need be, can be placed under the charge of the steam-engineer. The dynamos feed into copper bus wires, supported on the walls by porcelain insulators.

Each machine has its independent ampère meter, and in addition there is a general ampère meter at the end of the positive bus bar. From this bar the current passes to special snap-switches, each switch being connected through a three-plug safety-switch back to one of the feeders supplying current to the main line-wire. These feeder-wires tap into the line-wire at different points on the line of road, thus maintaining the pressure approximately equal all along the line. At the ends of the feeders in the central station, pressure-indicators are attached, which indicate the voltage at the junctions of the feeders with the main current-wire.

The engine-room is brilliantly lighted by handsome hanging electroliers, each of which has five incandescent lamps. A switchboard at one end of the room furnishes an independent control for each group of lamps. All the surroundings of the machines are kept in the neatest condition.

Adjoining the power-house, but separated by thick brick walls, is a commodious house for accommodation of cars, 107 feet long by 80 feet deep, designed to hold 24 cars.

The overhead system, which is built under the Sprague patents, is of the finest description, and includes iron poles set in concrete throughout the entire length of the road. These poles are of a very neat and tasteful pattern, and support the span-wires which carry the trolley-wire at a height of 18 feet over the centre of the track. This overhead wire, which is used for a working conductor, is made of silicon bronze, of the small Sprague type, only three-sixteenths of an inch in diameter. This is the only wire suspended over the middle of the track, and its lightness and high tensile strength allow the overhead supporting structure to be of the lightest description possible. The poles are 125 feet apart.

The return circuit is through the rail, and thence by both metallic and ground circuits to the station. Each section of rail is joined to copper ground wires throughout the length of the road underneath the string-pieces. At intervals of 500 feet this ground wire is connected to an earth plate, and at seven points widely distributed. The ground wire is connected to the station, and there is also a main ground connection made there through a large sink-plate.

In the overhead system a new method of switching has been adopted, which is at once ingenious and simple. Five or six feet inside the turnouts a small switch with flaring rider is interpolated into the main and branch wires, and a spring tongue upon this directs the path of the trolley with absolute certainty and ease. By this means, switching is made very easy, and all danger of the trolley leaving the wire is obviated.

The cars can be run at widely different speeds, varying from the slowest crawl to twelve or more miles per hour. They can be