(Paper No. 2664.)

(Abridged.)

"The Anglo-Chilian Nitrate Railway, Tocopilla to Toco."

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TOCOPILLA is situated in Algodon Bay, about 700 miles north of Valparaiso. There is little level ground on the coast of the northern part of Chili. A range of mountains, *Serrania de la Costa*, runs parallel to the coast, rising to a height of 2,000 to 3,000 feet; and immense quantities of débris have been carried at some remote time from these mountains and ravines, forming great banks sloping to the sea. Sometimes these banks are continued almost to high-water mark, and then descend with a steep bluff. Between this range of mountains and a second range, there is the first *pampa*, or plain; and on crossing this second range, about 30 miles distant, is the *pampa negra*, where the Caliche deposits are found, extending 30 to 40 miles from north to south, along the valley of the Rio Loa, with an average width of 4 to 6 miles. There are also copper, silver, and lead mines, and large borax deposits. Early in 1886 Mr. William Stirling, of Tacna, made a survey and report, which led to the formation in London of "The Anglo-Chilian Nitrate and Railway Company," for the construction of a railway from Tocopilla to Toco, and the erection of works for dealing with the nitrate[1] in the grounds they propose to acquire.

The most practicable route lay along the northern side of the hills bounding the ravine leading to Toco, winding in and out from one ravine to another, to reach Barriles at the level of the pampa, and crossing the cart-road at three places without interfering with it (Fig. 1, Plate 9).

The work was begun at Tocopilla in August, 1888, but little progress was made till the following January. The formation of the line reached Toco early in January, 1890, and the rail-laying was completed in March, 1890. Tocopilla Station is south

[1] "The Santa Isabel Nitrate Works, Toco, Chile," G. M. Hunter, Transactions Inst. of Engineers and Shipbuilders of Scotland, vol. 36, p. 57.

of the town, 55 feet above sea-level. The line is level for about $\frac{1}{4}$ mile to the south, where there is a reverse; then it begins to rise with a gradient of 1 in 40, gradually increasing to 1 in 25, for $4\frac{1}{2}$ miles, where there is another reverse, 796 feet above sea-level (Fig. 2). The gradient of 1 in 25 is continued to Barriles Station at $17\frac{1}{4}$ miles, except where the sharp curves necessitate a flatter gradient of about 1 in 30, the line skirting the sides of the hills, passing round rocky spurs, and crossing the ravines. At Barriles the line enters upon the first pampa at an elevation of 3,285 feet. The curves of the line, with radii of 716 feet to 181 feet, forming occasionally almost complete circles, make the line to Barriles between 5 and 6 miles longer than the road. Beyond Barriles, towards Toco, the curves are comparatively few and of moderate radii, none of those on the pampa being of less radius than 716 feet. The line rises with gradients of 1 in 40 to 1 in 33 from Barriles Station to the Central Station, at $26\frac{1}{2}$ miles, and thence with gradients of 1 in 66 to 1 in 50 to the summit at Ojeda, at $33\frac{3}{4}$ miles, 4,902 feet above sea-level; it then descends by easy gradients to the terminus at Santa Isabel at an elevation of 3,626 feet, $54\frac{3}{4}$ miles from Tocopilla. There is a short tunnel near Quillagua Station, through a spur of the hill, and a small wooden bridge over the road near Ojeda. Native labour was wholly employed on the work, the Chilians proving themselves to be industrious, and dexterous with the wedge, by which they excavated the rock. The northern part of Chili being rainless, it was rarely necessary to provide culverts for disposing of surface-water, and consequently all the ravines were filled with materials from the hillsides. In some cuttings, exceedingly hard rock was encountered; while in others it was soft, and was completely pulverized by blasting.

The gauge of the railway is $3\frac{1}{2}$ feet, which, in the Author's opinion, is the dimension best adapted for a rugged country. It is much less expensive in earthworks, bridges and rolling-stock than is the standard gauge, while it admits of the use of equally wide rolling-stock. The cuttings are 10 feet wide, and the embankments 9 feet wide at formation-level, with slopes of $1\frac{1}{2}$ to 1; while rock cuttings stand at $\frac{1}{4}$ to 1. The flat-bottomed rails weigh 40 lbs. per lineal yard, and are spiked to native oak sleepers, 8 inches by $4\frac{1}{2}$ inches, varying between 7 and 9 feet in length, 2,420 in one mile. The rails as far as Barriles have alternating joints, which saved a great amount of labour and expense, owing to the very numerous curves. In spite of sole-plates and of double-spiking the outer rail in the curves, a heavy

train coming down the steep gradient and entering a sharp curve, widened the gauge, pressing out the spikes. Clip tie-rods, Fig. 3, were therefore introduced, four to each rail on all curves of less than 300 feet radius; these were made of flat iron, $2\frac{1}{2}$ inches by $\frac{1}{4}$ inch, in two pieces, bolted in the centre for ease in fixing, the outer ends being turned over the outer flange of the rail (Fig. 5). They have proved of great service in maintaining the gauge of the line, are easily applied, and do not weaken the rail. The weight of the permanent way, including sleepers, is 170·45 lbs. per lineal yard. The cost of maintenance is £6 8*s.* per mile per month.

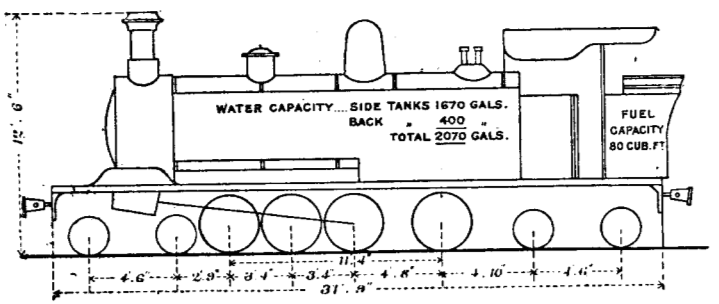
The site of Tocopilla station was in former ages covered by the sea, and has been subsequently raised to its present level (55 feet) by volcanic agency, as indicated by the frequent beds of marine shells encountered in the excavations, which were so consolidated that blasting was necessary. The traffic on the railway is controlled by telegraph, and there is also telephonic communication between Toco and Tocopilla.

Pier.—The iron pier is constructed of 5-inch steel piles, with a superstructure of plate-girders; cross girders, 18 inches deep, are placed on cast-iron caps on the top of the piles, with 15-inch rail-bearing girders between each row of the cross girders. The pier is 400 feet long and 42 feet wide, with a recess, 23 feet wide and 30 feet deep, at the extreme end for berthing launches (Figs. 4 and 5, Plate 9). There are four rows of piles to each bay, spaced 15 feet apart longitudinally and 13 feet transversely; while at low-water level there are horizontal struts to each pile, formed of two channel-bars back to back, and vertically the piles are braced with $1\frac{3}{8}$-inch tie-rods. Below low water, all the piles at the extreme end are braced, as also are three bays near the middle of the pier. The pier is 13 feet above high water, the rise of tide being 4 feet; and at the extreme end there is a depth of 26 feet at low water.

The foreshore at the site of the pier consists of hard rock with a fairly uniform surface, having a slope seawards of 1 in 13. Holes were, accordingly, jumped in the rock in order to fix the pile ends. "Jumpers" of 6-inch faces were used, with temporary clamps having four handles; they were lifted by four men, given a quarter-turn, and dropped. When the solid rock was reached, a man stood over the top of the "jumper," and assisted with a blow from a sledge-hammer at each turn. A hole to receive a pile was thus prepared in one to three hours. Most of the piles had to be placed by divers, as, although the piles were lowered from sheer-legs

exactly over the hole with ½-inch clearance all round, they were inserted with difficulty, and had to be turned round and assisted by blows from a sledge-hammer until the solid rock was reached. After a row was placed, the channel-bar struts were fixed, the level was taken, and the pile was cut off by a special cutter, in which the tools worked diagonally, one cutting V-shape and the other square. By this means the piles were cut in twenty-five minutes, instead of three to four hours, which was the time occupied by the original cutters. After a time, the men could complete two-and-a-half to three bays per week. The cast-iron screws sent out were only used in the first three bays, which are on shore. Longitudinal sleepers, 12 inches by 8 inches, are laid on the rail-bearing girders, to which the rails are spiked; and 4-inch decking is laid between, with ½-inch spaces. Walings, 12 inches by

Fig. 6.



12 inches, and fenders, 12 inches by 8 inches, are placed along each side to low-water; and two flights of steps are placed at the extreme end, on the outer sides of the recess, giving access to boats at high- or low-water (Figs. 4 and 5). Owing to the heavy surf which breaks on the coast during June and July, the erection of the pier was frequently attended with considerable danger, both to the men and to the completed part of the work; and on two occasions the temporary staging was completely wrecked.

The hydraulic plant includes a 3-ton crane with a radius of 20½ feet, and two 30-cwt. cranes with radii of 19 feet, having a lift of 30 feet. The accumulator and pumps are at the end of the pier. The pumping-engines have 10-inch cylinders with a 15-inch stroke; and the accumulator is 10 inches in diameter with a 10-foot stroke, giving a pressure of 700 lbs. per square inch. There is also a 25-ton travelling gantry crane capable of lifting a weight from a launch in the recess, and carrying it the full length of the pier. The erection of the pier occupied ten months.

Rolling-Stock.—The locomotives, of a special type to suit the heavy gradients and sharp curves, are eight-wheel-coupled tank-engines, with leading and trailing bogies, and outside cylinders 17 inches in diameter and 21 inches stroke; the heating-surface is 975 square feet, the grate-area is 16 square feet, and the steam-pressure is 160 lbs. per square inch; their weight when loaded is $51\frac{3}{4}$ tons (*Fig. 6*). Taking the mean pressure of the steam in the cylinders at 120 lbs. per square inch, the tractive force is 18,916 lbs. These engines draw four, and sometimes five loaded wagons of coal and general merchandise, weighing 80 to 90 tons, up the $17\frac{1}{4}$ miles incline of 1 in 25. From Barriles to the summit they draw ten to twelve cars, weighing 180 to over 200 tons.

The wagons are of the low-sided platform, double-bogie type, 22 feet long and $6\frac{2}{3}$ feet wide, with sides 9 inches high, and hold 15 tons. Several of the wagons are fitted with sides 30 inches high for carrying coal. The covered goods-wagons are 30 feet long. All the rolling-stock is furnished with Turton central buffers and draw-rods, and with automatic vacuum-brakes. Without these brakes the running of loaded trains would be very dangerous; for, besides the heavy gradients, the curves are so numerous that a train is often on two, and sometimes on three, curves at one time; while the high banks of the cuttings on either side prevent the engine-driver from seeing the train or controlling the actions of the brakesmen. The brake-blocks are of cast-iron.

Buildings.—All the stations, workshops, houses, &c., owing to the want of other materials in the locality, and especially to the frequency of severe earthquakes, were constructed of Oregon pine framing covered with galvanized corrugated iron. The outer walls of all the buildings were painted and coated with a species of fine white broken shells, which improves their appearance, preserves the iron, and is easily cleaned by a jet of water from a hose.

The Author acted as Assistant Resident Engineer during the construction of the greater part of the work, and on the retirement of Mr. William Stirling, became the Resident Engineer.

The Paper is illustrated by several drawings which have been reproduced in Plate 9 and in the text, and by a statement of the cost of the works, which is presented in the Appendix.

APPENDIX.

Cost of the Works.

Note.—The cost can be only approximately given, as the rate of exchange ranged, during the three years of construction, from 29*d.* to 22*d.* The cost of the machinery is given less freight, insurance and other incidental expenses.

	$	£
Forming the line	767,000	
Laying the permanent-way .	253,000	
Stations, buildings, &c. . .	200,000	
	$1,220,000	
At, say, 24*d.* exchange		122,000
Permanent-way materials		35,307
Rolling-stock, including erection at Toco-pilla		29,320
Pier with hydraulic plant		12,577
Machine-tools, &c., for workshops . . .		9,600
Telegraph-wire, instruments, &c. . . .		600
		£209,404

CALAÑAS THARSIS RAILWAY.

Fig: 1.

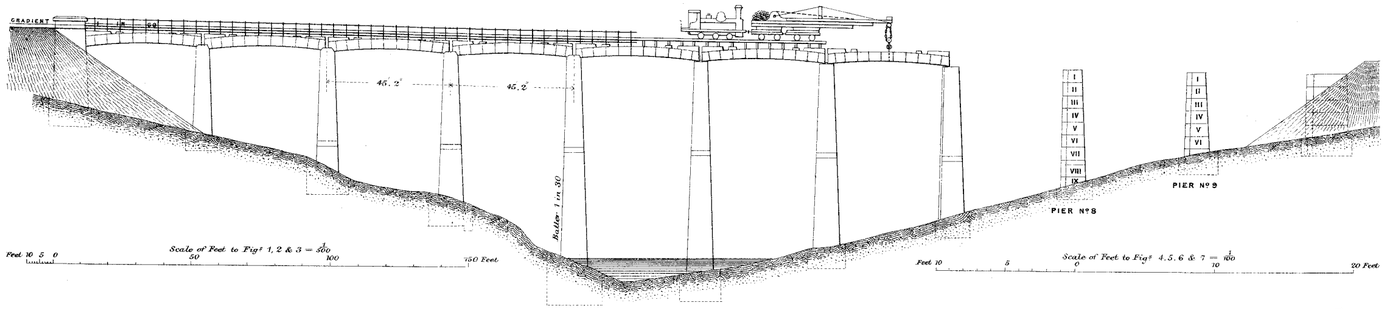


Fig: 2.

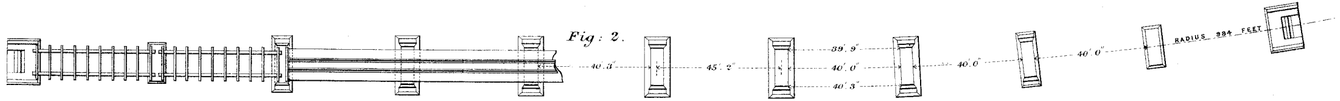
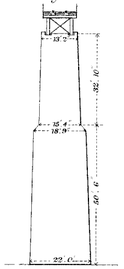
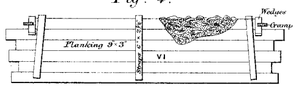


Fig: 3.



CENTRAL PIER.

Fig: 4.



CONCRETE BOX.

Fig: 5.

PLAN.

Fig: 6.

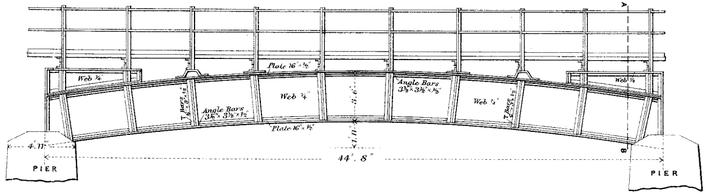
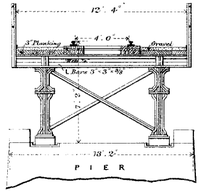


Fig: 7.



SECTION AT A.B.

A.M. ANDERSON.

ANGLO-CHILIAN NITRATE RAILWAY.

Fig: 1.

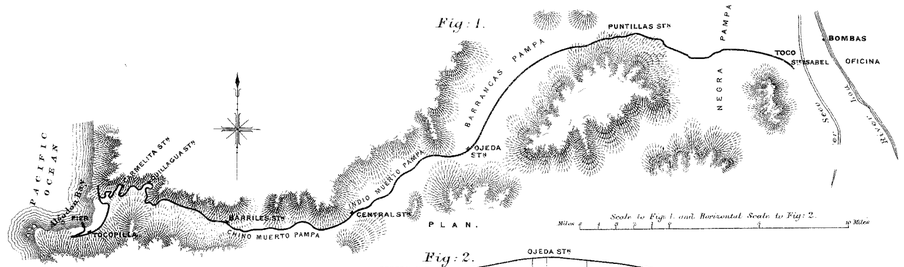


Fig: 2.

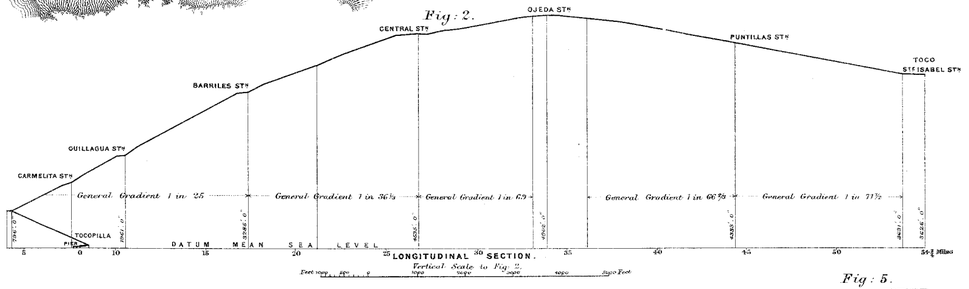
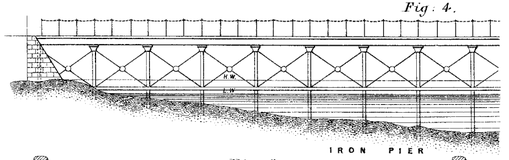
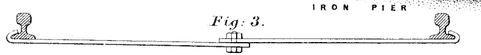


Fig: 4.

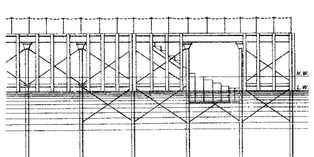


IRON PIER

Fig: 3.

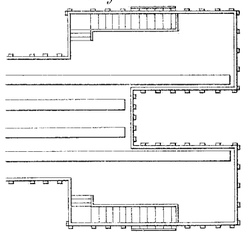


CLIP TIE-ROD FOR RAILS



Scale to Figs 3 & 4.
Feet

Fig: 5.



PART PLAN.

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