Mr. PADDISON observed, that the line was originally intended to go along Point Concon, and thence up the valley of Quillota. That route had been commenced before Mr. Maughan's arrival in Chile, at which time, considerable progress had been made in the cuttings. The whole of the coast consisted of decomposed syenite, and the hill-slope, facing the sea, was covered, to a thickness of 20 feet, with sand, which, in dry weather, the wind drove into the cuttings so rapidly, that it was impossible to keep them open; and, in wet weather, the cuttings were entirely filled by the land waters. Therefore it was already a question whether the coast line should not be abandoned. But Mr. Lloyd wished to have some practical information before coming to that decision. Shortly after his arrival a violent storm occurred, by which works to the value of £60,000 were rendered practically useless. Battens of 20 feet scantling were washed away into the sea, and cuttings 30 feet deep were filled up, and it then became a subject of serious consideration, not merely whether that route should be abandoned, but whether the line should be constructed at all.

Mr. FOWLER, V.P., said, there were two points of importance which had not been alluded to. One was, whether, at the junction of reverse curves, a straight piece was inserted, and if so, of what length; the other was, as to the cost of working the line.

Mr. PADDISON called attention to the section of a reverse curve of 600 feet radius, with a gradient of 1 in 50. In that instance, owing to the tortuous nature of the valley, it was impossible to insert any straight line. As a rule, a straight piece was inserted where practicable. He was not prepared with any information as to the cost of working. The price of earthwork varied from 1*s*., to 1*s*. 6*d*., and 2*s*. per cubic yard.

Mr. EDWARD WOODS said, the Paper was a record of one of the most important works carried out in South America. He had been connected with the line from its first projection down to the present time, and had supervised the construction of the materials for its permanent way, iron bridges, and working plant. In its general features, it resembled in many respects the other lines that had been constructed in that country. As stated in the Paper, all the lines connected the coast with the lower part of the mountain range, therefore all had to encounter severe inclines, and required that extremely sharp curves should be used. On the Copiapò Extension line there were gradients for about twelve miles of 1 in 30, eight miles of 1 in 23, and two miles of 1 in 27; so that the whole twenty-eight miles consisted of steeper gradients than those on the Valparaiso line, whilst the curves were of smaller radius—the sharpest being of 500 feet. With respect to the Copiapò Extension Railway, owing to the steepness of the gradients, it was proposed, in the first instance, to work with animal traction; consequently the rails laid down were lighter than if it had been intended to use locomotive power. But after the opening of the line, a severe drought rendered fodder scarce, and the expense was found to be so great, that though mules were used for twelve months, it was determined not to continue that mode of working, and it became necessary to design engines adapted to those steep gradients and sharp curves, having reference also to the lightness of the rails, which weighed only 42 lbs. to the yard. With respect to the construction of those engines, in the first instance it was a necessary condition, that the weight on any one of the wheels should not exceed 7 tons; for the rails were not strong enough to be subjected at any one point to a greater pressure. To obtain the necessary adhesion and evaporative power, the weight had to be subdivided, and be distributed upon three pairs of driving-wheels and a four-wheeled truck in front. The engines were accordingly constructed with that view; the three pairs of driving-wheels were 4 feet in diameter; the cylinders were 16 inches in diameter, with a length of stroke of 24 inches, and the front end rested on a 'bogie' truck, on four wheels. By that arrangement, these engines had been able to pass round the sharp curves with the greatest ease. In other respects, the construction was similar to that of engines in England. The boilers were of ample size, and the total weight of each engine did not exceed 30 tons in working condition, with a tender of about 20 tons (loaded). The loads averaged from 50 tons to 60 tons, exclusive of the engine and tender, on the gradient of 1 in 23. The length from the centre of the leading driving-wheels to that of the trailing-wheels was 10 feet 9 inches. The leading driving-wheels had no flanges, in order to facilitate the passage round the curves. Those engines, manufactured by Messrs. R. and W. Hawthorn of Newcastle, from the time of their being placed on the line till the present time (a period of three years) had worked without a day's interruption, and without accident. When first called upon to design the engines for the Santiago and Valparaiso Railway, he had some prejudice against the truck arrangement, and he decided upon the ordinary English construction, allowing considerable endlong play in the axle of the hind driving-wheels, so as to admit of its yielding to the curvature. The result was upon the whole satisfactory, but he had received complaints of the great wear and tear of the flanges and tires arising from the friction in passing round the sharp curves. It seemed, that recently, that difficulty had been in a great measure overcome by the application of jets of water to the wheels. He thought, that application was, in such cases, valuable, and one which might render bogies unnecessary where the curves were not extreme; but he inclined to the opinion that the simple Bissell bogie construction was the best for these lines.

He had recently sent out for the Coquimbo line, a tank engine, connected with a two-wheeled bogie truck, and he had received a report stating, that nothing could be more satisfactory than the working of it. It rounded the sharpest curves with great ease, at a speed of 30 miles per hour, and ran as smoothly as a first-class carriage.

There was one observation in the Paper, with reference to the screw pile, which had attracted his attention. The screws were stated to have been provided for a bridge across the Viña del Mar river, and to have proved unsuccessful, the structure having been carried away by a flood. He did not think the same result could be predicated of the use of every kind of screw, which might be adapted for hard, or for soft ground, as circumstances required a different form and pitch. With regard to the cost of working lines in Chilé, the consumption of coke on the heavy gradients of the Copiapò line was about 70 lbs. per mile. Coal had not yet been employed, but it was hoped to introduce it with success and economy, by using the native coal, instead of importing from England, which could only be done at a great expense. The average working speed of the line was about 12 miles per hour.

One circumstance worthy of remark was the great rapidity with which the works of the Santiago and Valparaiso Railway were executed after the Government had undertaken them—a rapidity which, he believed, so far exceeded expectation, that the line was ready for opening five months before the stipulated time, and long before the rolling stock was prepared, so that the early traffic had to be carried on with such plant as was at hand. He might add, that in consideration of the rapid completion of the work, the contractor received the bonus offered by the Government.

Mr. PHIPPS inquired, what amount of super-elevation was given to the outer rails on curves of 500 feet or 600 feet radius, for a speed of 30 miles per hour? He considered that any experiments, confined to the pulling of a single wagon, were an insufficient test of friction; and that when a train was drawn slowly, over a curve of small radius, there might be a greater pressure against the inner rails than the outer ones.

Mr. WOODS replied, that the average speed was not more than 15 miles or 16 miles per hour upon curves, when, he thought the super-elevation of the outer rails would be from 3 inches to 4 inches.

Mr. PADDISON stated that, on the reverse curves of 600 feet radius, with an inclination of 1 in 50, the super-elevation was 5 inches.

Mr. VIGNOLES begged to add his testimony to the extreme amount of ingenuity, courage, and skill with which the works had been carried out. There was no railway he knew of in any part of the world in which such great objects had been accomplished in so economical a manner. He had carefully perused the Paper (not knowing anything of the Author, or of the country except generally), and after inspecting the plans and the photographic views, he would say, he knew nothing equal to them. Although he might take exception to some of the details, he not only assented to the conclusions, but went further, and attributed a greater amount of resistance to the curves, and consequently of power to overcome that resistance, than had been set down in the tables.

Mr. GILES did not quite understand whether, on a gradient of 1 in 40, there was a curve of so small a radius as 600 feet. He would also ask whether in Chile, where, judging from the photographs, there was a great abundance of stone, the Engineer would not have found it more economical to substitute stone, instead of cast-iron, piers, for the viaducts, considering the long carriage and the necessarily expensive nature of iron work in that country?

Mr. VIGNOLES said, it was stated in the Paper, that iron-work was used for various reasons, and amongst others the sufficient one, he thought, of obviating, as much as possible, the effects of shocks of earthquakes. Speaking from his own experience, he found that in such countries, notwithstanding the abundance of stone, it was better and cheaper to make embankments in some cases, and to employ iron-work in others, although the iron required a considerable amount of cartage; because the lime and sand were not found with the stone; and, that being the geological character of Chilé, he thought the Author had exercised a sound judgment in using iron.

Mr. WOODS said the reasons given by Mr. Vignoles for preferring iron to stone were quite correct. The question of earthquakes was one that required the attention of Engineers carrying out works in volcanic countries, both as regarded ordinary buildings and railway constructions; and under any circumstances, the erection of large masses of masonry was objectionable. That was one reason no doubt why iron had been used Iron structures had a degree of elasticity which prevented their being injuriously affected by slight shocks of earthquakes. Another reason in favour of iron was the great cost of skilled labour in the country, in addition to which, there was the question of time; ironwork prepared in England and sent out, being erected so much more quickly than masonry. The curves prevailed over almost all portions of the line, including the long incline of 1 in 40, and that was the case also on other lines in Chilé. Sharper curves and steeper gradients were common, and he had previously mentioned one line on which the gradients were 1 in 23, 1 in 27, and 1 in

30, and he was reminded that, on the Semmering incline of 1 in 40, there were curves of 600 feet radius.

Mr. COLBURN could not agree with the statement, that the resistance was doubled on a curve of 1,000 feet radius, and that a resistance of 15 lbs. to the ton occurred on a curve of 700 feet radius. He thought any one who had had much practice upon railways, would be opposed to the belief, that the resistance was as great as was assumed in the Paper. He was once familiar with a piece of road on an American line, where the rise was 20 feet to the mile, with a level curve of 700 feet radius at the top. He had been up and down that line many hundreds of times, and he had repeatedly observed, that in ascending, the engine increased its speed on passing from the ascent on to the level curve. The driving-wheels might be making 180 revolutions per minute in ascending the 20 feet rise; but the speed increased to 190, 200, and even 210 revolutions on the curve; and as, in that case, the gravity due to the incline was less than $8\frac{1}{2}$ lbs. per ton, the resistance due to the curve could not have been more than 6 lbs. or 7 lbs. per ton. On a decline of about 27 feet to the mile, he had seen carriages run down through curves of 1,100 feet radius without coming to a stop in the curve, although the gradient was but little more than the angle of friction. About eight years ago he made a number of experiments for the superintendent of the New York and Erie Railway—a line of 450 miles in length—with a view to ascertain what a single engine would draw over every part of that line. The gradients and distances of each section were:—Eastern division 74 miles long, gradients of 1 in 88 both ways; Delaware division 104 miles long, gradients of 1 in 354 going west, except for 15 miles between Deposit and Susquehanna, where there were inclinations of 1 in 88 both ways; 'Gulf Summit,' near Susquehanna, being 1,360 feet above the sea; Susquehanna division 140 miles long, 1 in 528 both ways; and Western division, 128 miles long, 1 in 132 going east, and 1 in 105 going west, 'tip top' summit 1760 feet above the sea. A train was started at Dunkirk, on Lake Erie. The engine had outside cylinders, 17 inches in diameter, with a length of stroke of 24 inches, and four coupled 5-feet driving-wheels, with a weight of about 18 tons, or 40,500 lbs. on both pairs of driving-wheels. The train was started, with all the load that could be got, over the inclines on the Western division. When Hornellsville was reached a train was in waiting there, consisting of one hundred 8-wheeled loaded cars, each weighing upwards of 15 tons. The whole weight of the train, as far as Susquehanna, was 1,570 tons, with the engine, the train being more than half a mile in length. Some portions of that line were practically level, though at places there were gradients of 10 feet to the mile. On the level and straight portions and through the curves of 900 and 1,100 feet radii the train, consisting of eighty wagons, was taken at a speed of from 10 miles to 12 miles per hour. At Susquehanna it was divided, and consisted of twenty-two wagons to Deposit, 15 miles east of Susquehanna. From Deposit to Delaware was 90 miles, over which the whole train was taken, and a great part of that distance was level, with a succession of curves of 956 feet radius. The train went through those without any difficulty, the load being 1,570 tons. Supposing the resistance had been 10 lbs. to the ton, there would have been a tractive power required of 15,700 lbs. He regretted, that at that time they had no indicator diagrams; but there was never more than 130 lbs. pressure in the boiler, and, taking that as the pressure on the piston, it would have given only a little more than 15,000 lbs. tractive power, so that there could never have been more than 10 lbs. pull per ton upon any part of that train. He believed the adhesion was $\frac{3}{8}$ths of the weight on the driving-wheels. If in the instance referred to, the adhesion was less than 15,000 lbs., it effectually disproved the assumption of double resistance on a curve of 1,000 feet radius. He was quite sure, the resistance on curves was nothing like 15 lbs. per ton, on a radius of 700 feet, and as to its being doubled on a radius of 1,000 feet, he was quite convinced it was nothing of the kind.

Mr. Bidder, Past President, said, it must be borne in mind, that the resistance on a curve was not the same at all velocities. The resistance of a curve was a function of the velocity; but he could not understand how a tractive power of 15,700 lbs. was got out of a weight of 18 tons on the driving-wheels. That was different from anything Engineers were acquainted with in England.

Mr. Colburn said, the proportion between the weight on the driving-wheels and the adhesion was, in this country, assumed at $\frac{1}{6}$th or $\frac{1}{7}$th. He found, from his own observations on the Great Eastern Railway, that it was $\frac{1}{4}$th, on the Brentwood incline. His statements as to the weight of the train referred to, might be entirely relied upon, as he knew exactly to what weight the cars were loaded. Sand was freely used on the rails when necessary. He thought, sometimes there were more than 130 lbs. of steam on the boiler, and even with that pressure, there was a difficulty in accounting for the resistance of the train. The resistance could not have exceeded 10 lbs. to the ton, at parts of the road where he should have expected it to be 15 lbs. He regretted that no further details of the experiments were published, beyond what were furnished in a report to the Directors of the New York and Erie Railway Company; but he promised a Paper giving the results of these trials to the Institution.

Mr. Bidder, Past President, said, the difficulty was as to the adhesion, and if a Paper were brought before the Institution during the present session, he should like to have that question discussed, inasmuch as at present he was not prepared to admit an adhesion of less than 1 in 3. At the same time he should be happy to have his theory corrected by absolute facts. With sand there would be more adhesion, and the resistance of 10 lbs. per ton would then probably become 15 lbs. or 20 lbs. per ton.