

SECT. II.—OTHER SELECTED PAPERS.

(Paper No. 3509.)

“Railway Construction in North China.”

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THE first standard-gauge (4 feet 8½ inches) railway in China, the original section of the system now known as the Imperial Railways of North China, was constructed in 1880–1881, and connects the Tongshan Collieries with the head of the Lutai Canal, 7 miles distant (Fig. 1, Plate 6). An account of the great difficulties met with in the construction of this line and in its subsequent extension to Tientsin in 1888, has already been published by the Institution.¹ So successful was this work that the Chinese Government decided to extend the line westwards from the original starting-point; this extension was proceeded with after many unavoidable delays, chiefly due to the opposition of the people, who drove back the first survey-party in 1888, and delayed the work for years.

The rails reached the Ma Chia Pu terminus, outside Peking, in 1897. In 1899 an electric tramway was laid to the South gate. From a point near Peking the railway to Pao Ting Fu was next constructed; this line was opened in 1899, and has already been described in the “Proceedings” of the Institution.² A new city station was subsequently opened in Peking, at the Chien-Men, and a branch-line eastwards to Tungchou was constructed in 1901.

Eastwards from Tongshan the railway was gradually pushed on to Shan Hai Kuan, where the Great Wall of China meets the sea and almost on the boundary between Chihli and Manchuria. The extension was opened to Kuyeh in 1890, to Lanchou in 1892, and to Shan Hai Kuan in 1893. At Lanchou is the largest, although

¹ C. W. Kinder, “Railways and Collieries of North China.” Minutes of Proceedings Inst. C.E., vol. ciii. p. 278.

² T. J. Bourne, “The Construction of the Lu-Pao District of the Lu-Han Railway.” Minutes of Proceedings Inst. C.E., vol. clii. p. 157.

not the longest, bridge on the system; it consists of five spans of 200 feet, ten spans of 100 feet, and two spans of 30 feet. This bridge was opened on 27 February, 1894. It was intended at that time to prolong the line to Chinchou, Mukden and Kirin, and surveys were made. A considerable amount of earthwork was done as far as Ta Ling Ho, but want of funds seriously hampered the work, and the war between China and Japan, declared on 1 August, 1894, not only stopped operations but swallowed up the funds and completely altered the whole political situation in North China. By 1896 the rails had been laid only to Chung Ho So, 40 miles from Shan Hai Kuan. To enable progress to be made, it was necessary to put the funds on a firmer basis, and in 1898 a preliminary agreement was made to raise a loan in London for the purpose of extending the line to Hsin Min Tun and Yingkow (Newchwang) with a branch to Nan Piao, where there is a good coalfield. The Russian Government strongly objected to this, and a long diplomatic battle ensued, one result of which was an important alteration in the original agreement, to the effect that the new lines were not to be mortgaged to meet the services of the loan, and finally, on 10 October, 1898, an agreement was arrived at between the Administrator-General of Railways and the Hong Kong and Shanghai Banking Corporation, to raise a loan of £2,300,000 for the purpose of executing certain works on the old line, paying off former loans, and extending the railway as already described, the total length of the extension, east of Chung Ho So, being 270 miles.

The work has been completed within the estimate, and in this Paper the Authors propose to describe the Chinchou-Yingkow section, 97 miles in length, commencing $\frac{1}{2}$ mile east of Chinchou; and to supplement the general information given in the two Papers already referred to. The line as far as Chinchou was opened for traffic in October, 1899.

CHINCHOU-YINGKOW SECTION.

The survey for the Chinchou-Yingkow section was completed in April, 1899, and the laying of the rails was finished in December of the same year. Deviations were made round bridges, and as little work as possible was done in advance of the track-laying, in order to get the benefit of rail transport. By the spring of 1900, all the bridge-foundations except those of Ta Ling and Shuang Tai Tzu bridges were finished, a wharf was built at Yingkow, the

stations and buildings were well advanced, and the plant and material necessary to complete the work were on the ground, when the Boxer outbreak completely upset all arrangements. The head office was burned to the ground, the Director-General was killed, and the other directors had to flee for their lives; 130 miles length of the line from Peking to the East of Tangku was rooted up, the buildings were demolished, and the Engineer-in-Chief and his staff were besieged in Tientsin. Although the railway from Chinchou to Yingkow was not much damaged, the whole country was in violent disorder. The foreign staff made their escape to Newchwang, and the railway was taken over by the local military authorities, who destroyed a part of the temporary bridge at Shuang Tai Tzu as a military precaution and held the line till October, 1900, when it was taken by the Russian military authorities. In order to keep open their lines of communication, the Russians repaired the railway, ferried locomotives across the river, and reopened traffic with a trans-shipment at Shuang Tai Tzu in April, 1901. By the month of August the Shuang Tai Tzu temporary bridge was rebuilt by the Russian military engineers, and trains were run through again. Several bridge-tops were permanently finished, and buildings were erected to accommodate the troops, but nothing was done to the permanent work of the bridges at Ta Ling Ho and Shung Tai Tzu, or to the ballasting, etc., as the object was simply to keep the trains running, pending developments. Besides the Chinchou-Yingkow section, the Russians held the line as far as Shan Hai Kuan, and also the construction-stores and bridge-works at that place. After protracted negotiations, the line was returned to the Chinese Government on 10 October, 1902, and immediately afterwards the engineering staff resumed control, but little could be done during the winter season, and it was not until the spring of 1903 that the necessary materials were obtained and operations were again commenced. After another interruption, due to severe floods, the rails were finally laid to Hsin Min Tun, in the Autumn of 1903. Pending the opening-up of the coal-field, the Nan Piao branch, 30 miles in length, has not yet been constructed.

Excluding the Pao Ting Fu line, the total length of the railway and extensions is 588 miles. The total expenditure on the lines, when completed, will have been about £3,850,000.

The Peking line, 78 miles in length, was originally a double line and cost £10,000 per mile, but after the Boxer outbreak it was relaid as a single line, and the remaining rails and girders were used for the Tungchou extension, 20 miles in length, and for

relaying the Tangku-Tientsin section, in order to have 85-lb. rails right through from Tangku to Peking, the Tangku-Tientsin section originally having only 70-lb. rails.

General Description of Route.—Chinchou, the starting-point of the section to be described, is a walled city near the north-west corner of the Gulf of Liao Tung (Fig. 1, Plate 6.) From Chinchou to Ta Ling Ho, $15\frac{1}{2}$ miles, the route lies among hills; from Ta Ling Ho to Kou Pang Tzu, 25 miles, along the plain at the foot of the hills; and from Kou Pang Tzu to Yingkow, 57 miles, across the flat alluvial plains forming the head of the gulf. At Kou Pang Tzu is the junction for the Hsin Min Tun line, which is 70 miles in length. Yingkow, the terminus, is on the right bank of the Liao river, which is navigable for steamers up to Newchwang, and for river-boats for 200 miles into Southern Manchuria. The route to Hsin Min Tun was laid out to run through the centre of a grain district. The junction for the Yingkow line is so fixed that the route from Kou Pang Tzu (the junction-station) is the shortest possible. There would have been no advantage in keeping nearer the coast, as the plains across the head of the gulf are salty, unfertile and scantily populated. All trees, except a few around villages or near graves, have long ago been ruthlessly cut down, and hardly any timber can be obtained locally. The nearest accessible coal-mine is about 300 miles away, and neither metals, gravel-pits, nor brick-clay are found near the line.

Survey.—Chinese maps partake more or less of the nature of a pictorial sketch, sometimes giving a fair idea of the district, but no measurements can be taken from them and they are of little use for railway-work. The chief difficulty in making a survey is to avoid graves, which are scattered about everywhere, instead of being collected in cemeteries. The burying-grounds of wealthy people practically cannot be touched; graves belonging to poor people were avoided if possible, but where it was necessary to remove them a money compensation was arranged and the coffins were interred at another place. Another difficulty is to ascertain flood-levels, and to estimate the effect of the embankment on floods. The river-channels, in general, have gradually become silted up, and after a heavy rainfall the adjacent plains are inundated. From Chinchou to Ta Ling Ho a route was found which offered easy gradients and curves, the worst gradients being 1 in 200, about 2 miles in length, and the sharpest curves of 3,000 feet radius, the worst point of the line being where these occur at the same place. From Ta Ling Ho to Yingkow, across the plain, the gradients are very slight.

Spring and autumn are the best seasons for outdoor work in North China. Between 15 June and the early part of September heavy rains may be expected, and work in the river-beds must be arranged accordingly. In winter, in southern Manchuria, there is an unbroken spell of frost from the end of November until March, the night-temperature being sometimes 10° below zero Fahrenheit. During the winter season, however, the roads are in their best condition, and most of the transport is done then.

Land.—As soon as the location, pegging out, and levelling of the centre-line were completed, the side-widths were calculated and a list of them was given to the Chinese official appointed to buy land and to pay compensation for removal of graves. Land-buying in China is an art, requiring the services of an expert. Many of the plots are small and crooked in shape, the boundaries between adjacent plots being difficult to trace. The result is that the railway land boundary is far from straight.

After the railway was completed, stones were put in to mark the boundaries and a survey of them was made. Special surveys were made, to a larger scale, of all land near stations; this is the only land which increases much in value after the railway is built, and it is quickly encroached upon by neighbouring land-owners if not carefully looked after. A large area was bought for each station-site, and parts not immediately required were rented out.

The average price of land was 10 dollars¹ per mou² (equal to £5 17s. per acre), and compensation was paid for removal of graves at an average rate of 5 dollars (8s. 9d.) each, most graves containing only one coffin.

Earthworks.—The earthwork for the whole line was let to a Chinese contractor who had done a large amount of similar work on the lines previously constructed. He was supplied with a list of the heights of embankment or depths of cutting at each peg, and was told the width of formation and the inclination of slopes required. He employed several thousand coolies, who lived in huts of mats stretched over bamboo half-hoops. Each man has a shovel, and two baskets carried at either end of a shoulder-pole; an alternate method, rarely used for contract work, is by means of a large basket carried on a shoulder-pole by

¹ The average value of the dollar during 1902-3 was 1s. 9d., and this value has been adopted in calculating the English equivalents for the various rates given in the Paper.

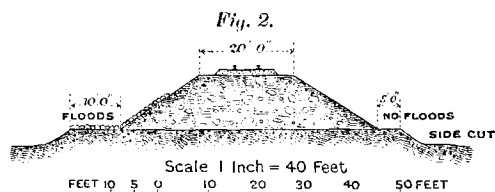
² 1 mou = 6,510 square feet.

two men. The embankments were all made from side-cuts, and the spoil from cuttings was heaped up in mounds on either side. The height of the highest embankment is 35 feet, and the depth of the deepest cutting is 20 feet. The Yingkow yard, where, on an average, 7 feet depth of filling was required, was partly done from borrow-pits in the yard and partly from others 2 miles away, the earth being brought in trains of twenty-five cars, each of 200 cubic feet capacity and taking 6 cubic yards of excavation.

The rates of payment for the earthwork were :—

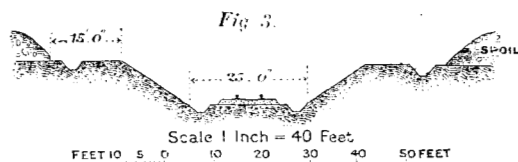
	Per Cubic Yard.
All work between Chinchou and Yingkow	1.1 <i>d</i> .
Filling at Yingkow (station borrow-pits)	1.7 <i>d</i> .
" " " (haulage by train)	1.4 <i>d</i> .

The contractor found all his own tools, etc., but paid nothing for rent of engine, cars, etc., which would probably add another 0.8*d*. per cubic yard to the price of the filling by train haulage at Yingkow. Between Chinchou and Ta Ling Ho are several



cuttings through rock of varying hardness. These were let out in separate contracts to different contractors at an average price of about 9*d*. per cubic yard. Gunpowder, drill-steel, etc., were supplied to these men at cost price, and any surplus on completion of the contract was paid for at the Engineer's valuation, which was rarely disputed. The Chinese are excellent at earthwork, but not so good at rock-cutting. They drill only small holes, and use very small charges of explosive. A section of the embankment, which was built throughout with a formation-width of 20 feet, is shown in Fig. 2; the slopes are $1\frac{1}{2}$ to 1, with the exception of small lengths which required a slope of 2 to 1. A section of the cutting is shown in Fig. 3; it has a formation-width of 25 feet, and side-slopes of $1\frac{1}{2}$ to 1, which were required even through most of the rock-cuttings, as the rock, although hard to excavate, quickly disintegrated on exposure to the atmosphere. Through country not exposed to floods, a berm of 5 feet is left between the toe of the embankment and the edge of the side-cut. The berm is increased to 10 feet in districts subject to floods. Pitching is often

placed on it and up the slope to about 2 feet above highest flood-level, for protection against waves. Willows are also planted, and with their long roots afford excellent protection against floods. When grown to sufficient height, they shield the trains from side-winds, a protection by no means to be despised in a country where high winds are frequent during many months of the year. Where the soil is suitable and the natural growth is not rapid, the slopes are sown with grass-seed, but in the salty ground between Kou Pang Tzu and Yingkow nothing has been found to grow well, and the slopes are pitched with stone where they are exposed to heavy floods. Between the top of the cutting-slopes and the toe of the spoil-heap a berm of 15 feet is left, and a surface-drain is cut in it. When the banks were first constructed, they were made higher at the sides than in the centre; this was done in order to allow them to become saturated by the rain-water, and to insure rapid and proper settlement. Before rail-laying was commenced they were re-formed, and a slope was made from the centre to the edges in the usual way. Ample



allowance was made for settlement, and in few places is the formation below the level at which it was originally intended to be, after complete settlement. A large portion of the earthwork between Chinchou and Ta Ling Ho was completed before the outbreak of the Japanese War, but that between Ta Ling Ho and Yingkow was only started in April, 1899, and was finished in September of the same year. This does not include the filling at Yingkow or at the ends of each bridge. Excluding the filling at Yingkow, which amounts to 245,643 cubic yards, the earthwork amounts to 4,549,724 cubic yards, or about 46,900 cubic yards per mile. The amount of rock-cutting was 53,160 cubic yards.

Track.—The Chinchou-Yingkow extension is laid throughout with steel flange-rails of Sandberg standard section, weighing 60 lbs. to the yard, this weight of rail being now in use over the whole system, except between Tangku and Peking, where heavy locomotives are run and an 85-lb. rail is laid. The 60-lb. rail has a $2\frac{1}{2}$ -inch head and a flange $4\frac{1}{2}$ inches in width, and is $4\frac{1}{2}$ inches in height. The angle fishplates, 2 feet 2 inches in length, and weighing

52½ lbs. per pair, are fixed with four $\frac{7}{8}$ -inch bolts, and are spiked to the joint-sleepers, to prevent creeping. The sleepers are of Japanese hardwood, 8 feet by 9 inches by 6 inches, and have an average life of 6 years, the rails being spiked to the sleepers with square spikes. The cost of the sleepers was 1s. 11d. to 2s. 1d. each, delivered at the Railway Company's wharf. To each 30-foot rail there are thirteen sleepers, spaced 2 feet 5 inches apart, centre to centre, except near the joint, where the spacing is 2 feet 2 inches, and at the joint itself 1 foot 6 inches. The track amply fulfils the requirements of the traffic; high speed is not necessary, a maximum speed of 40 miles an hour for passenger-trains and 20 miles an hour for goods-trains being sufficient. With an axle-load of 13 tons for locomotives, trains of 130 loaded axles are worked on the easy sections; this compares well with the loads on many lines having much heavier rails and engines. The ballast is all rock obtained from the nearest quarries, no gravel ballast being available. It is laid to a depth of 8 inches under the sleepers, and has a top-width of 11 feet level with the tops of the sleepers. The ballast was specified to be broken to pass through a 4-inch ring, but a fair percentage of it was considerably larger, in spite of the contractors being fined and made to send men out on the line to break it. The sub-contract price for the ballast, loaded into cars, was between 6½d. and 9d. per cubic yard, the price varying at different quarries. Rail-laying was conducted from both ends of the line. From Chinchou the existing line was extended and all materials were brought forward from Tangku, but before starting at the Yingkow end a wharf had to be built for the landing of locomotives, cars, and track material, the rolling-stock, of course, being erected on the spot. For purposes of rail-laying, a portable track of 2 feet gauge, $\frac{3}{4}$ mile in length, was laid along the edge of the formation. The rear end of this track overlapped the rail-head train, and all materials were unloaded on to the 2-foot-gauge trolleys, pushed forward, and spread out by coolies, who left everything ready for the spiking and bolting gang. Another gang following straightened and packed the track, so that trains could be run to the rail-head a few hours after the track was laid. Owing to the length of the dry season, a very good track can be kept without ballast, and no temporary or service roads were used to distribute the materials. A day's work in track-laying was $\frac{1}{2}$ to $\frac{3}{4}$ mile, including deviations round bridges and sleeper-stack temporary bridges where required. The work was done partly by contract, at a cost of 1·4d. per lineal yard, including the cost of the trolley-track, unloading materials, carrying them forward, laying, spiking, and bolting the track, and

packing and straightening it sufficiently for a train to be run over it without damage to the rails. No charge was made for tools supplied to the contractor. The ballasting was done by special ballast-trains of twenty to twenty-five cars, holding about 17 cubic yards each. These cars were unloaded through side doors by means of shovels. The track was lifted in two lifts, and after it had been well packed and straightened the top-ballast was spread. The rough packing was done by contract; the price paid for unloading the ballast, lifting the track 8 inches, and leaving it well packed and straightened, was 1.6*d.* per lineal yard. This contractor was followed by a gang of men paid by time, who thoroughly packed and straightened the road, making it ready at once to receive trains running at 20 miles an hour. The track is maintained by regular gangs of six men, who have to look after 10,000 feet of track. A flying-gang is put on when necessary to do any extensive work which cannot be accomplished satisfactorily by the regular gangs. Over each five or six regular gangs is placed a section foreman, who reports to the Engineer. If possible, his house is built near a station, so that he can communicate with the Engineer by telegraph. Mileage- and gradient-stones, instead of being placed facing the line, are set at right-angles to it and can be seen for some distance from an approaching train. The mileage-stones are 5,000 feet apart, and the figures on them represent the distances, in chains of 100 feet, from the starting-point at Tangku.

Bridges.—Between Chinchou and Yingkow there are forty-one bridges, with a total of 157 spans, as well as a number of 3-foot, 4-foot, and 6-foot culverts. The total opening given by bridges is 7,090 feet, or 73.1 feet per mile. The older sections have a much greater opening, and between Shan Hai Kuan and Chinchou the bridge-work is very heavy, namely, 194½ feet of opening per mile. In addition there is a weir 500 feet in length, bringing the total opening to 7,590 feet, or 78.2 feet per mile. Dressed granite was used for some bridges, which were built before the main shipment of cement arrived, and also for facing parts of piers exposed to floating ice at Ta Ling Ho and Shuang Tai Tzu. With these exceptions, concrete was used throughout. The granite courses are about 1 foot in thickness and 2 feet in width on the bed, the mortar used being gauged 3 to 1. In general, the concrete consisted of broken stone, sand and cement, gauged 6, 3 and 1 for foundation-work, 8, 4 and 1 for piers up to 12 feet in height, 6, 3 and 1 for piers exceeding 12 feet in height, and 4, 2 and 1 for the top 18 inches or

2 feet of all piers and abutments. The stone, broken to pass through a 2-inch ring, was brought by rail from the nearest quarry. Sand was obtained in several river-beds between Chinchou and Yang Chuan Tzu, but for the rest of the line it was obtained from a river-bed a few miles up the Hsin Min Tun branch. With a few exceptions, where the ground was hard and not liable to be scoured out by floods, all bridges were founded on piles 16 feet to 24 feet in length. The heads of these piles are embedded 6 inches to 9 inches in the concrete foundation-block. The spans are of the standard lengths adopted on the Imperial Chinese Railways, namely, 10 feet (arch), 12 feet, 20 feet, 30 feet, 60 feet, 100 feet, and 200 feet. The top-widths of the piers are 3 feet, 3 feet 3 inches, 4 feet and 6 feet, for the 12-foot, 20-foot, 30-foot and 60-foot spans respectively, the lengths varying between 14 feet and 18 feet for the various spans. The girders are all of the Imperial Chinese Railways' standard, and are of the deck type, with the exception of the 200-foot span at Shuang Tai Tzu, which is of the through type. No over-bridges were required, as level crossings satisfy all the requirements of the country. The bridges are decked with Oregon-pine timbers, 10 feet by 9 inches by 8 inches, spaced 20 inches apart, centre to centre, notched and bolted to the upper flanges of the girders. Guard-rails of Oregon pine, 6 inches by 6 inches, are notched and bolted to these ties. Rubble pitching is placed round all end piers and abutments. Most of the river-channels are too small to carry off the flood-waters, and many of the bridges are intended as flood-openings to take the water which spills over their banks. Where there is a regular channel, training-banks have been built out from the line to direct the water through the bridge and to prevent eddies round the piers as much as possible. At flood-openings, where water often comes from all directions and largely along the railway-bank, these training-banks leave the railway-bank gradually and are well rounded off at their ends. This counteracts the tendency of the water to cut through the training-bank close to the bridge. Where the flow of water is strong, aprons of rough pitching have been laid to prevent scour under the piers, but as all the bridges, where the ground is soft, are founded on piles, there may be considerable scour without risk of damage to the bridge. Drains and culverts are built of concrete or of large granite slabs. At one or two places where the headway was small, old rails were embedded in the concrete of the roof, or a deck was constructed of old boiler-plates and rails riveted together, covered with 6 inches thickness of concrete and well tarred on the lower side, which was exposed

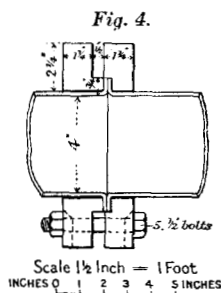
to the water. All concrete was mixed by hand, the Chinese coolies trained to this work being very expert at it. Several piers between Tientsin and Peking were partly blown up by the Boxer rebels, and the material proved to be excellent. The finely-ground Alsen cements were invariably used for the more important works.

The girder-work is all of Siemens acid open-hearth steel and was designed to carry a rolling load consisting of two typical engines having 20 tons on the driving-axles, followed by a train of $1\frac{1}{2}$ ton per lineal foot. The heaviest engine at present in use weighs, with its tender, 106 tons, and has an over-all length of 56 feet. The weight of the decking and permanent way is taken as 400 lbs. per lineal foot. Wind-pressure is taken as 56 lbs. per square foot when the bridge is not loaded, and 40 lbs. per square foot with a train on it. The working-stresses allowed are very low, $5\frac{3}{4}$ tons per square inch being the maximum for girders up to 200 feet span, with the exception of the wind-bracing, where $8\frac{1}{2}$ tons per square inch is allowed. For small spans, and for the centre diagonals and counter-bracing of the larger spans, the stress must not exceed $4\frac{1}{2}$ tons per square inch. The range of temperature in North China being about 120°F. , ample provision has to be made for expansion. The bearing-plates of all girders up to 30 feet span rest on 6-inch Oregon-pine wall-plates, well tarred and secured to the tops of the piers. The 60-foot spans are provided with plain sliding-plates, well bedded and secured to the tops of the piers. All girders exceeding this length have roller-bearings. It is inadvisable to use sheet-lead under girder bearings in China, as it would be quickly melted out and stolen. Girder-seats rest directly on the concrete of the piers, but are kept 6 inches back from the face, this 6 inches of the pier being bevelled off. All girders on the Chinchou-Yingkow line are riveted structures, and with the exception of the 200-foot span at Shuang Tai Tzu and some 30-foot and 60-foot spans, were built in the railway bridge-shops at Shan Hai Kuan. It is intended that the next 200-foot spans required shall be built in these shops, as work turned out by them is considerably cheaper than that from Europe or America, and is equally good. Latterly rolled joists well braced together have been adopted for the 12-foot and 20-foot spans, as being cheaper than the ordinary built-up plate-girder.

Air-plant.—All the air-plant is the property of the Imperial Chinese Railways; the compressors and boilers were obtained in England, and the locks and shafting were constructed in the

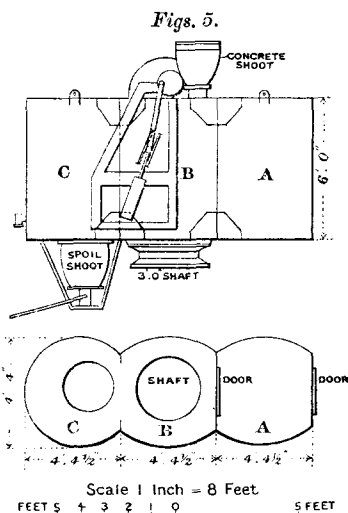
bridge-shops at Shan Hai Kuan. There are also two heavy air-locks of English construction, but these are now only used when there is great pressure of work. The air-compressors are horizontal engines with the steam- and air-cylinders, each 12 inches in diameter, placed tandem. The engine has a stroke of 24 inches, is provided with two heavy fly-wheels and a governor, and runs up to 70 revolutions per minute, delivering at that speed 220 cubic feet of air per minute, measured at atmospheric pressure. The engine channel-bar frame is bolted to a heavy timber frame which can be embedded in the ground. The air-cylinder is kept cool by means of an internal water-spray, the pump for which is worked by connecting-rods from the main piston-rod. Two vertical boilers, 8 feet in height by 4 feet 9 inches in diameter, with Galloway tubes, are provided for each engine, and supply steam at a pressure of 80 lbs. per square inch. They have close fire-bars to enable them to burn dust-coal.

The compressed air is delivered into a receiver; for four engines a receiver 13 feet 6 inches in length by 6 feet in diameter is generally used. This receiver is fitted with a pressure-gauge, and also a blow-off cock to get rid of the water introduced by the spray. From the receiver the air passes into a 4-inch main pipe, a smaller branch-pipe and valve being put in opposite each air-lock. These branches are connected to the locks by 2½-inch pressure-hose. The main supply-pipe is made of wrought iron. The end of each length of pipe is pressed out to form a flange ⅝ inch in width; between these faces a piece of



rubber insertion or other packing is placed and the joint is made secure by bolting together two cast-iron flanges slipped along the pipes, *Fig. 4*. Most of the air-locks were specially designed by Mr. Kinder for portability and rapid working. Unfortunately the drawings of these locks were lost during the Boxer outbreak, but a rough sketch of the lock is shown in *Figs. 5*. Each lock consists of three chambers bolted together. They are taken apart only when it is necessary to carry them in Chinese carts over all sorts of roads. Chamber A (*Figs. 5*) is intended for the entry and exit of men passing in and out of the lock; it is also used for passing out boulders which are too large to go through the spoil-shoot. It is entered by a door opening inwards, another door on the opposite side giving

admission to chamber B. Two small cocks, one over each door provide means for regulating the pressure in this chamber. Chamber B is directly over the caisson-shaft, which is 3 feet in internal diameter, and to which it is bolted. To the roof of this chamber is bolted the concrete-shoot and also a dome in which is placed the winding-drum and band-brake. The concrete-shoot is wholly outside the lock, and has two doors, one at the top opening into the shoot itself, and the other at the bottom opening into the lock; *i.e.*, they both open downwards and against the pressure. Chamber C opens directly off chamber B without any communicating door; in fact, when bolted together they form one oblong chamber. The air-supply pipe delivers directly into this chamber, which has a spoil-shoot below the floor, and a spring safety-valve on the roof. The spoil-shoot has one door at the top, opening upwards into the lock, and against the pressure, and another at the bottom, opening downwards, or with the pressure. The gear, situated outside the lock, for opening the lower door, is designed so that this door cannot be opened unless the top door is shut. In one of the old locks not provided with this safety device, a man was blown through the spoil-shoot and killed, owing to the failure of the locking-gear, which had a defective forging. The lock is lighted by 9-inch dead-lights in the roof. To the outside of chambers B and C a steam-winch is bolted, having one cylinder on either side of the lock. The crank-axle, which carries the winding-drum, passes through the dome of chamber B, which is kept air-tight by stuffing-boxes. The reversing-gear and stop-valve are on the top of the lock, where the driver sits. This winch has cylinders of $4\frac{1}{2}$ inches diameter and 16 inches stroke, and is supplied with steam from the boilers in the compressor-house if near to them, or otherwise from isolated boilers erected for the purpose. The spoil is hauled up the shaft in iron buckets 2 feet in depth and 1 foot 3 inches in diameter, by means of $\frac{3}{8}$ -inch or $\frac{1}{2}$ -inch steel-wire rope. The bottom of each bucket is closed



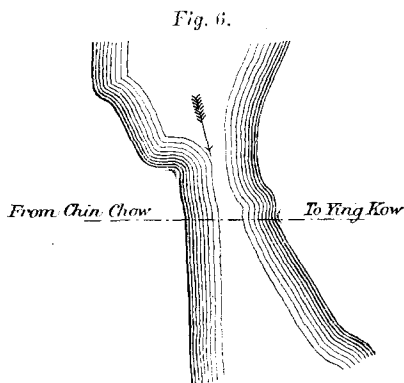
with a catch, and is opened to drop the spoil as soon as the bucket is pulled over the spoil-shoot. The shaft is 3 feet in diameter, is made of $\frac{1}{4}$ -inch steel plates with angle-bar flanges, 3 inches by 3 inches by $\frac{1}{2}$ inch, and has an iron ladder riveted to it. All doors and joints are kept air-tight with $\frac{1}{2}$ -inch rubber. The men inside the lock communicate with those outside by a system of knocks. The lock complete with engines, etc., weighs 4 tons 7 cwt., and, when taken apart in three sections for road transport, no part weighs more than 1 ton 5 cwt., or measures more than 8 feet $2\frac{1}{2}$ inches by 4 feet $4\frac{1}{2}$ inches by 4 feet 4 inches. The height of each chamber is 6 feet, and the volume about 96 cubic feet, the length over all being 13 feet 6 inches. One complete lock is transported on four small carts, one of which contains a specially-made iron chest for the fittings.

The total cost of the air-plant, divided by the number of cubic feet of caissons sunk by its means, and allowing 75 per cent. for depreciation, interest, and general overhaul, but not including minor repairs while in use, averages 1.2*d.* per cubic foot. This rate has been taken as the rent of the plant in estimating the cost of bridges. The Chinese have not yet been required to work under air-pressures greater than 30 lbs. per square inch, but so far as they have been tried they have proved admirably adapted for working in compressed air, and fortunately it is unnecessary to make them conform to the very strict rules which are imperative for Europeans. A set of such rules is given to the gangers, but with limited supervision it is quite impossible to see that they are obeyed. Notwithstanding this, during the last 10 years there have been only two cases of men being overcome.

Ta Ling Ho Bridge.—The Ta Ling Ho, in the neighbourhood of the railway-crossing, is approximately 1 mile in width, but a point where it is confined by two rocky spurs to about half this width (*Fig. 6*) was chosen for the bridge-site, the east abutment being built on the spur on the left bank. The west approach is by a short bank a little over 20 feet in height, which is partly washed by the flood-water and therefore had to be protected for some distance with rubble pitching; the east approach is through a cutting of soft rock (*Fig. 7, Plate 6*). Beyond this cutting are sand-hills which extend for some 600 feet and are liable to give trouble, but screens made of millet-stalks about 6 feet in height and curved so as to direct the prevailing winds against the hills, have been erected as a protection to the line, and are cutting away the sand, which previously mounted up over the rails. During the dry season the water is split up into several channels, having an aggregate width of about 500 feet and a depth of 3 to 5

feet, the rate of flow being not more than 4 feet per second. These channels invariably alter their course with the slightest rise in the water-level, but such rises rarely occur except at the break-up of the frost, when they do not exceed 2 or 3 feet, and in the rainy season, when they may be anything up to 10 feet and the flow very rapid. The river-bed is composed of the finest yellow silt, giving rise to violent dust-storms in the high winds which prevail during winter and spring. From the middle of November until the middle of March the river is frozen over, ice forming to a thickness of 2 feet, and the water below runs clear, whereas at all other times it is highly charged with silt and has a very muddy appearance.

It was decided to bridge this river with twenty-six spans, each 100 feet in the clear, giving a bridge 2,762½ feet in length between the abutments—the longest bridge on the whole railway system. All the piers, and the west abutment-pier, are founded on caissons sunk by the pneumatic process, but the east abutment is founded directly on the rock-spur, which rises above the river-bed. Concrete was used throughout for the caissons and piers, except the east abutment, but



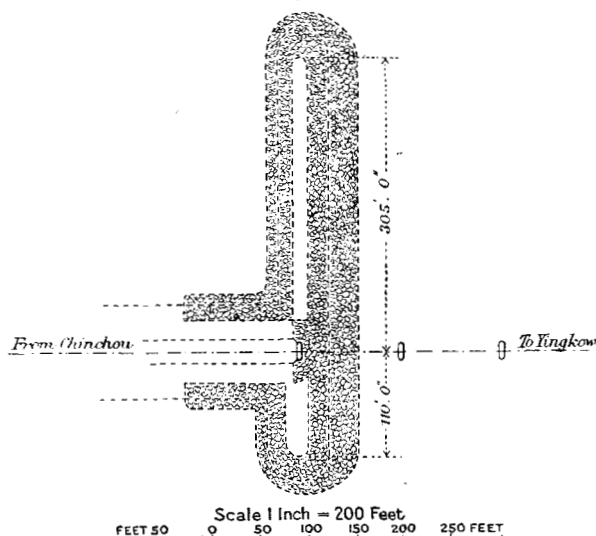
for the facing of those parts of the piers which are exposed to floating ice, granite masonry was employed. The details of the caissons and piers are illustrated in Figs. 8, Plate 6. The most noteworthy feature of the caissons is the small amount of metal sheathing used, there being none above the level of the 4-foot curb-plate. Beyond this level no protection was given to the concrete, nor does it appear necessary. The cutting-edge was made of angle-bars, 3 inches by 3 inches by ½ inch, to which were riveted the curb-plate and another angle-bar, the latter being also riveted to the inner shell or working-chamber. The working-chamber was constructed of ¼-inch steel plates riveted together. The 3-foot air-shaft up the centre of the caisson and carrying the air-lock on top was bolted to the roof of this chamber, which was stiffened with channels and angle-bars.

When the caissons reached the required depth the working-chamber was filled with concrete under pressure and was left for 6 or 7 days before the air was shut off. As soon as the air-lock and shafting had been removed, the shaft-chamber, which measured 8 feet by 4 feet, was filled with clean sand to within 5 or 6 feet of the top. After this sand had settled, the last length was filled with concrete and the masonry-work was commenced on the top. The granite-masonry facing, with concrete hearting, was carried up course by course, the stone-masons dressing the beds of the stones before setting, and dressing the tops ready for the next course the day after they were set. This method is universally adopted by Chinese masons, and ensures good joints. It is very difficult to get them to dress the stones with parallel faces before setting and then to set them true to level. The top 20 feet of the piers is of concrete, gauged 6, 3 and 1, except the last 1 foot 6 inches, which is gauged 4, 2 and 1. Moulds for this concrete were made of 4-inch Oregon-pine planks placed vertically, with deep walings and three angle-bar straps right round the mould. Templates were used inside the mould, the parts of which were wedged up against them, off the angle-bar straps. The moulds had temporary openings at heights of 10 feet and 15 feet, through which the coolies carried the concrete, thereby avoiding a deep drop and saving labour in carrying all the concrete up to the extreme height of the mould. The scaffolding used consisted of tier upon tier of iron cement-drums filled with stone or sand, with sleepers placed across them, and could be quickly erected and taken down. All the concrete was carried in baskets up planks laid on this scaffolding. The men carrying ballast, sand and cement to the mixing-boards, mixing cement, carrying it up the scaffolding, depositing and ramming it, as well as rearranging the scaffolding for the different heights, handled, on an average, 20 cubic feet of materials per man in 11 hours' work. The concreting of each pier was started and finished the same day. A good face was obtained by working shovels down between the concrete and the mould. The latter was removed 36 hours after the last concrete was deposited and the piers were then rubbed down with sand and water by means of wooden trowels. In only one pier were there any holes on the face larger than a finger-print. Plums of clean rubble were rammed into the concrete, care being taken to keep them well apart and back from the face.

The concrete was mixed on old iron plates or close-boarded platforms. The sand and cement were mixed dry with shovels until the mass was of a uniform colour. The stone was spread

alongside and watered, and then the sand and cement were thrown evenly over it. The whole mass was turned over several times and thoroughly mixed, enough water being used to make the concrete easily worked without being sloppy. Much of the caisson-work was done in winter, when the water had to be heated and sea-salt had to be added to it. As little water as possible was used and in no case was the concrete damaged by frost, although the temperature was frequently as low as zero Fahrenheit during the nights. The amount of salt required was ascertained by putting out various mixtures of salt and water each night and seeing which of them froze. All concrete made in winter was thickly

Fig. 9.

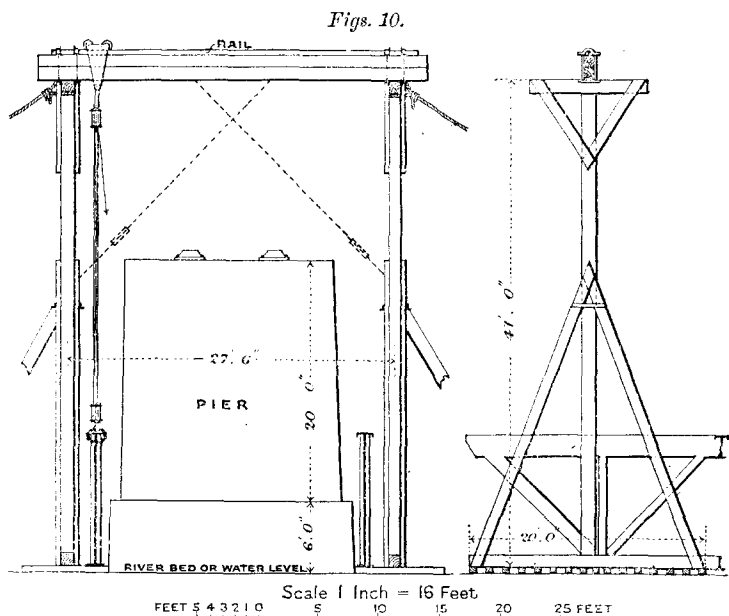


covered with straw as soon as it was finished. Owing to the frequent dust-storms the ballast had to be repeatedly cleaned either by washing or screening. The sand was obtained from sand-pits in the river-bank and was rather fine, but clean and fairly sharp.

Pier No. 1, the west abutment, is similar to the other piers, but is buried in the bank, the river-slope of which is heavily pitched, and is provided with a 30-foot apron of rubble, 3 feet in thickness. A training-bank, extending 300 feet up-stream and 100 feet down-stream, forms a continuation of this pitched slope and apron (Fig. 9). The pier is backed by a wall of hand-packed rough ashlar,

10 feet in thickness, being too slender to support the weight of the bank at the back, should the river-slope and pitching be washed away.

The girders are of the inverted Warren type, but with vertical posts from each of the lower joints. They are riveted throughout and rest on cast-iron bed-plates bolted to the piers. They weigh 38 tons per span complete. Eleven of the spans were erected on sleeper-stacks. Sheer-legs, 40 feet in length, were mounted on trolleys running along a track of 4 feet 8½ inches gauge. Each span was unloaded from the railway-cars, pulled over to the bridge,



and, by means of the sheer-legs, erected over the pier, in 4 days of 10 hours each by fifty men, no tackle but a few blocks, Manilla rope and a hand-winch being required. The remaining spans were erected on the river-bed, or on staging, and were lifted by means of a gantry (*Figs. 10*). This gantry was originally made with up-rights 38 feet in height, but after the floods of 1903 the river-bed was scoured out and the water-level dropped 2 feet 6 inches; the height was therefore increased to 41 feet. In only a few spans was it necessary to erect staging in the water for this gantry, as the greater part of the work was done in the winter of 1903, when

the ice was thick and quite capable of bearing the weight when spread over sufficient area. After the girders of a span had been lifted, tie-rods were put in to brace the uprights to the top cross-beam and the gantry was moved along to the next span. This method was cheaper than that by means of sleeper-stacks, as forty men were able to unload and erect a span in 2 days, another 2 days being occupied in lifting the girders, putting in the bracing and moving the gantry to the next span. The field-riveting was all done by contract with hand-labour. Care had to be taken to provide sufficient clearance between the bed-plates and the end diagonals of the girders to allow for expansion. In order to ensure this, the lewis-bolts fastening the bed-plates to the piers were left loose until everything was in position, when they were grouted with cement.

A temporary wooden bridge was built, and trains were run across it in November, 1899. Work on the main bridge was not commenced until the end of the year, when ten air-compressors were installed and the foundation-work was begun. By the middle of June, 1900, twenty-two caissons had been sunk to depths of 32 feet or more; eleven of them were finished and had the first 5 feet or 6 feet of the piers built on them. At the breaking-up of the ice, a strong freshet came down and seriously tilted caisson No. 8, which had been sunk only a short distance. In order to straighten it the river-channel was diverted so that the current struck the high side and scoured out a hole; jacks were then brought to bear on the low side, and by this means, with the help of winches and tackle, the caisson was pulled over into an upright position; it had, however, moved slightly out of its place, and the pier had to be corbelled out some 8 inches over the caisson. Most of the records of the work done at this time were lost during the Boxer outbreak, which took place shortly afterwards. Previously to the suspension of work on the line on account of the outbreak, all the air-plant had been taken down and hauled up the river-bank, in view of the approaching rainy season. No further work was done until the line was handed back to the Chinese, in October, 1902. It was then found that although the air-plant was still there, it had been stripped of all its brass fittings by the Chinese. New fittings were made at the railway-shops at Tangshan and Shan Hai Kuan, which were working at full pressure to make good the damage done to the rolling-stock, etc., and by 27 December two compressors, three boilers and two air-locks were fitted up, and sinking-operations were commenced on two of the unfinished caissons. The sinking of these caissons was completed without

difficulty, although they had been standing for $2\frac{1}{2}$ years. It was not until the beginning of February, 1903, that four compressors could be got to work, and by slow degrees the number was increased to eight compressors, with twelve boilers. Two other boilers were used to supply steam to the lock-winchies, and ten locks in all were in use. Previous to the Boxer outbreak twenty locks had been employed. The curbs of the four caissons not previously started were pitched at the beginning of February. These being situated in the river-channel, the ice had to be cut away and islands of small rubble had to be made. The working-chambers were filled with sand to stiffen them, and concrete made with special small stone was filled in between the outer and inner skins. When this had set, a wooden mould of 3-inch planks was erected, and the concrete was built up to a height of 11 feet above the cutting-edge. After this had set properly, the sand was dug out of the working-chamber and sinking was commenced. When the top of the caisson was 6 inches above the level of the ice, sinking was stopped and another lift of concrete was put on. While this was setting, the ice and stone became frozen to the caisson, and although great pains were taken to break away the stone and ice, tilting of the caisson due to this cause took place in two instances. These caissons were afterwards partially but not wholly righted, and now the centre of pressure, when a train is on the bridge, is in one case 7 inches and in the other case 6 inches, to one side of the centre of the bottom of the caisson. While sinking was in progress, the locks were strutted off the top of the caisson to prevent their weight and that of the shafting bearing heavily on the roof of the working-chamber during a run, but the steel-plate sides of the working-chambers of two caissons were bulged in several inches, through workmen having removed these struts for some other purpose. This bulging started the rivets and joints, and caused serious leakage of air, besides leaving a permanent void between the steel and the concrete. The leakage was stopped with clay, but great care had to be taken in the sinking to prevent further damage. After the working-chambers of these caissons had been filled with concrete, the shaft-chambers were filled entirely with concrete, instead of sand being used for this purpose as in all the other caissons. The material met with during sinking was silt and sand for the first 15 feet, and then gravel right down to the bed-rock, which is a poor quartzite. This bed-rock was not considered sufficiently solid for the foundations to be laid upon its surface, and it appeared to extend down to a considerable depth. As, however, it showed no signs of scouring-action, it was decided

to sink the foundations only 4 feet to 6 feet into it. In caisson No. 14, when it had been sunk 22 feet, a piece of granite, which had been left in the river-bed before the Boxer outbreak, was met with. The maximum scour is probably not more than 25 feet to 30 feet, judging from the appearance of the gravel met with below that depth. A scour of 20 feet in depth was measured 2 days after the big flood on 28 August, 1903. The sinking through rock was a slow operation, and in four cases the caissons became wedged when 3 feet or 4 feet into the rock. As the rock had been excavated 1 foot 6 inches to 2 feet 6 inches below the cutting-edge, the excavation was thoroughly cleaned out and concrete was filled in. The tops of these caissons had to be afterwards blasted off to bring them down to the same level as the others. In all cases a rock core was left in the centre of the working-chamber to save excavation and concrete. In the 2½ years during which work was stopped, no damage was done to any of the caissons.

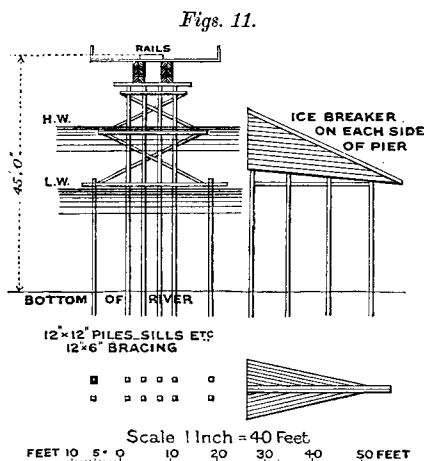
The work done in 1903 was carried on under considerable difficulty, as the boiler-power was insufficient, and only three feed-pumps could be provided for each range of six boilers. On very cold nights sufficient steam to drive the lock-winchies could not be obtained, although the steam-pipes were well lagged with felt. A considerable quantity of water found its way from the receiver into the air-pipe, and fires had to be lighted along the line of the pipe to prevent ice forming. The two engine-houses were in the river-bed but raised several feet above it. One of them was well back from the channel and was simply protected against freshets by rubble pitching. The other was on the edge of the main channel; it was built on a piled foundation, and the floor was filled in solid with sand, protected on the outside with rubble. In March a heavy freshet broke up the ice. The sand filling gave way owing to the water flowing under it, and was quickly replaced with rubble. The engines, boilers, etc., were not displaced, as they rested directly on the pile-caps. Beyond this and the loss of a considerable quantity of concrete ballast, the freshet did no damage to the main bridge, but the scour which it created under the temporary bridge necessitated throwing in some 600 cubic yards of track-ballast to save the bridge. The pipe-line rested directly on the heads of piles driven wherever it was thought that spring freshets might cause damage. The sinking-operations were completed by the first week in May, and the last pier was finished on 21 June, the building of the last nineteen piers, with three moulds, having occupied 29 days. The piers were then dressed by stone-masons to a uniform level. Seven spans of girders

were erected before the end of June, when work was suspended until after the rainy season. During the next two months several rises of 5 feet or 6 feet took place, but nothing serious occurred until 28 August, when the water rose 10 feet, the flood carrying away more than two-thirds of the temporary bridge. Some of the piles were afterwards recovered from the fields where the flood had dropped them. This afforded an excellent test of the piers of the main bridge, as the flood was the most severe that the natives had ever seen. After this flood no more girders could be erected until the temporary bridge was rebuilt. This required about 1,000 feet of piled bridging. The work was finished and trains were run across on 9 October. Erection of the girders was then resumed, and the bridge was opened to traffic on 18 January, 1904.

The caisson-sinking amounted to a total of 1,183 feet. The records of the cost of the work done before the Boxer outbreak were lost, but in making up the cost of the bridge they are assumed to be the same, item for item, as those for the work done subsequently. In all probability they were considerably less, as labour and materials were cheaper, and more of the sinking was done in warm weather, when the coal-consumption is much less and the labour is more efficient. The bridge contains 12,910 cubic yards of concrete and 590 cubic yards of granite masonry. The total quantity of cement used was 12,410 barrels. The caissons were sunk, on an average, to a depth of 45 feet 6 inches—the deepest being 55 feet—below water-level. The weight on the bases of the caissons, with a train on the bridge and excluding skin-friction, is between 4 tons and 5 tons per square foot. The caisson-curbs and the girders were all made at the Shan Hai Kuan bridge-shops. The costs of the bridge are given in the Appendix.

Shuang Tai Tzu Bridge.—At Shuang Tai Tzu, 61 miles from Chinchou, the railway crosses a tidal river, 500 feet in width and 33 feet in depth at high-water, and having a flood-depth of 36 feet. The range of tide is about 10 to 13 feet, and the velocity of the tidal current is 4 knots per hour, except during spring-tides with certain winds, when it is 5 to 6 knots per hour. Ice forms in winter to a thickness of at least 2 feet, and when this breaks up in spring large masses of it are driven up and down the river for a few days by the tides. The river-bottom consists of mud, and as more than a few feet of scour was not anticipated it was decided to sink caissons to a moderate depth, through islands of ballast and rubble, which would also serve as protection to the piers in the future.

Before the permanent bridge could be built, it being imperative to keep the construction-trains running, a temporary wooden bridge was built on a deviation. As some difficulty was experienced with this bridge, due to ice, it will be described. The first bridge had no ice-breaking piers, and, although it was stayed to the bank with wire-rope, part of the bridge was damaged by ice. Later on it was again damaged by the local military authorities to prevent communication by rail. When the Russian forces took the line, their engineers rebuilt the centre of the bridge in a stronger manner, and added ice-breakers. The final form, which stood the winter well, is shown in *Figs. 11*. The temporary bridge consisted of nineteen spans of 30 feet. Each pier was built on ten piles, 12 inches by 12 inches, in two rows. The total height to rail-level from the bottom of the river was 45 feet, of which the lower 22 feet was not braced. The girder-beams consisted of six timbers, 12 inches by 12 inches (in two rows of three logs each) under each rail, notched to prevent one log sliding on the other, thus making the whole beam stiffer than if the three logs had been merely placed one on top of the other. This method, how-



ever, is wasteful in a temporary structure, as the notched timber is depreciated. The speed of trains across the bridge was limited to 5 miles per hour, and under a 50-ton locomotive the deflection of the spans was $1\frac{1}{2}$ inch. The ice-breakers were on piles quite separate from the bridge-piles. On the upstream and downstream sides of each pier ten piles were driven, in the form of an isosceles triangle with 22-foot sides and a 14-foot base. The apex-pile was cut off about low-water level, and the centre base-pile about high-water level, the side base-piles being cut off a little above low-water level, thus forming a ridge with sloping surfaces on either side. These surfaces were planked over with 3-inch planks, and a stout tee-bar was fixed securely on the ridge. During winter the ice round the bridge-piers was kept broken in case the rising tide

might catch the bracing, but the space between the two rows of piles forming each pier became filled up solid with ice, within the tidal limits, as also did the space between these and the ice-breaker piles, so that when the pressure of the ice did come, it was really distributed over them all. Large masses of ice were driven against the bridges, and some split up, whilst others partly mounted the ice-breakers. In one case one of the ridge tee-bars was torn off and some of the planking was smashed, but the ice-block, thus impaled, itself acted as a protection, and no further damage was done. Without these ice-breakers the piers would have been pushed over or cut to pieces.

The permanent bridge consists of one 200-foot span, with five 60-foot spans as approaches (Fig. 12, Plate 6). The islands were made during winter, small round holes being cut in the ice and the ballast dropped through as required. The first train-load of ballast for the islands was unloaded over the temporary bridge in order that it should have to be carried only a short distance, but the ice had been so weakened by the open spaces round the pile-piers, that, although 2 feet in thickness, it was broken by one train-load, and the remainder of the ballast had to be unloaded on the bank and carried out. The same occurred at the holes through which the ballast was dumped; the smallest holes spread considerably and became so large that planks had to be laid over them. In the spring of 1902, when the ice had broken up, the islands were brought up to 2 feet above low water, and were dressed off level. The side-slope was 1 to 1, and the top was 3 feet larger than the caisson all round. Some rubble had to be placed afterwards to make up for ballast which had been washed off. The largest island is 22 feet in height above the original bottom. Rubble was thrown round the piled piers as required to counteract the scour caused by the islands, but the centre of the temporary bridge-spans was allowed to scour out. The construction of the islands effected a considerable saving in the cost of the caissons, which were made very light; the curb was formed from an angle-bar 5 inches by $3\frac{1}{2}$ inches by $\frac{3}{4}$ inch, the curb-plate was $\frac{5}{16}$ inch, and the other plates $\frac{1}{4}$ inch in thickness, all built on frames of angle-bars 3 inches by 3 inches by $\frac{1}{2}$ inch, 5 feet apart (Figs 13, Plate 1). The caisson was approximately elliptical in plan, 36 feet in length and 14 feet 4 inches in width, for the piers of the 200-foot span, and 26 feet 6 inches by 11 feet 6 inches for those of the 60-foot spans. The working-chamber was 8 feet in height, and three shafts and locks were provided for the caissons of the 200-foot span. Three locks were not required on one caisson as used at Shuang Tai Tzu; even

with contractors working three times as fast, two locks would have been sufficient, and the cost of handling the locks would have been reduced. Channel-bars were placed over the chamber roof to convey part of the weight to the sides, and vertical tie-bars were run from the bottom to the top of the concrete portion of the pier. The bottom of the chamber was 410 square feet in area, and was designed for a soft bed, the resulting pressure on the foundations, without allowing anything for skin-friction or displaced water or material, being $4\frac{1}{2}$ tons per square foot, and after allowing for these, probably 2 tons per square foot. The caissons were erected in situ; the curb was laid on the island, and the first course of plates was fixed, a few rivets being left out meantime to allow the water to enter, and the curb being also tied down to anchors in the river. As soon as the first course of plates was riveted, the space between the inner and outer plating was filled with concrete, gauged 4, 2 and 1. The caisson was then sunk 2 feet into the island by open sinking at low water, after which there was no danger of the current moving it; two more courses were then riveted on and concrete was filled in, bringing the top above high water. Each caisson was dealt with in the same manner, but in the case of the piers of the 60-foot span the caisson-plating was not carried up above the working-chamber. In the meantime the air-plant, which had been arriving from Ta Ling Ho as soon as it could be spared, was erected on the east bank of the river in a rough shed. It consisted of four compressors and eight boilers in the power-house, and two boilers outside for winches. One or two boilers were always out of use, for cleaning, as the water was very salt. The air-locks and shafting were the same as those used at Ta Ling Ho. With the exception of a light gangway to the islands, no staging of any kind was used in connection with the sinking of the piers. The first length of shaft, and the locks, were erected off the caisson-top. Progress was slow at first, as care had to be taken to keep the work plumb; the material also was hard, and no one could be found to undertake the work by contract; time-labour was therefore adopted, but under the circumstances supervision was difficult. After sinking had proceeded to a sufficient depth the locks were raised, another length of shafting was added, concrete was put in, and the process was repeated. After experimenting with different methods, it was found that the easiest method of raising the locks was by means of jacks on the pier, the locks being raised one at a time, so that during the operation work could proceed by the other two locks. The bottom length of air-shafting was concreted in, but above

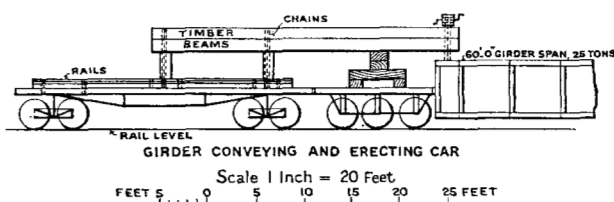
this length voids 6 feet by 4 feet were left in the pier, and after sinking the rest of the air-shafting was all recovered. Masonry was commenced at such a level as would give 5 feet depth of water over the concrete at low water. The stone used was grey granite from Shih Shan Chan, with concrete hearting. When excavating, sinking proceeded, on an average, at the rate of 1 foot per day, but delays due to concreting, etc., reduced the average to 6 inches per day. The masonry-work was slower, as 2 days were occupied in laying one course, and setting, during which time the excavating had to be stopped, as the debris resulting from the work spoiled the cement-mortar, which was gauged 3 to 1. The concrete hearting was the same as the caisson concrete above the level of the working-chamber, namely, 6, 3 and 1; the concrete round the working-chamber was gauged 4, 2 and 1. Below the river-bed about 15 feet depth of muddy sand was passed through, then several feet of dark compact soil with a few vegetable remains, below which clear dark sand was met with. The soil was evidently an old soil-line, and as it had apparently never been scoured out it may be assumed that the piers are perfectly safe at a depth of 24 feet, with the protection of stone pitching all round. The working-chamber was filled with concrete, and the shafts with chips and ballast up to the commencement of the masonry, which was built solid, with a tongue projecting down into the lower shaft. The piers were then completed up to finished level. The total depth below high water is 56 feet, and below rail-level 68 feet. The dimensions of the piers for the 200-foot span are shown in Figs. 13, Plate 6. Those for the 60-foot span were smaller. While the river-piers were being built, the land-piers were completed, each resting on thirty-four piles, 10 inches to 12 inches in diameter and 25 feet in length. The foundation-blocks and piers are of concrete, gauged 6, 3 and 1.

The girders for the five 60-foot spans were built at the railway bridge-shops at Shan Hai Kuan. They are plate-girders of the standard type adopted on the line, and weigh 25 tons per single-line span. These girders were erected by means of the cantilever-trolley illustrated in *Fig. 14*, which has been in use for years on the railway. Each of these trolleys consists of two cars, one being a three-axle flat car over which timbers project above the track at sufficient height to enable the end of the span to be hung without touching the rails, and the other, coupled to this car, being an ordinary flat car to which the timbers are also secured, and which is weighted to balance the suspended girder. The

other end of the span is slung similarly, and on these trolleys the girders are sent out on ordinary freight-trains, riveted up complete, thus saving all field-work, which is always more expensive than shop-work. At the site, two spans were crossed on logs propped up temporarily and having track laid upon them, with joints just clear of the ends of the girder of the first span. The trolleys were pushed on to the bridge and were stopped with the girder exactly over its proper place. The temporary logs to be replaced were knocked down, and the girder was lowered by winches from the trolleys. Track was then laid on the top of the girder and the trolleys were hauled away. With this apparatus, the time occupied between the arrival of the girder from the shops and the reopening of the line for traffic after placing the girder in position is 1 hour in daylight or 2 hours in the dark.

The 200-foot girder was made in England, and was shipped to China in pieces, the heaviest of which weighed $2\frac{1}{2}$ tons. The

Fig. 14.



platform on which to erect the girder was supported on seven rows of piles, six in a row, driven 15 feet into the river-bed and so placed as to be under the panel-points. The decking was of logs and sleepers laid down but not cut. The cross-girders and rail-bearers were erected first, and were brought to the proper height by means of large wooden wedges. On the top of the rail-bearer girders a track was laid, on which ran a 3-ton travelling-crane having a jib long enough to reach over the girder. The parts of the main girder were taken out from the bank on trolleys, and were placed by means of the crane. The main girders are of the Pratt type, 27 feet 6 inches in depth, the weight of the whole span being $158\frac{1}{2}$ tons; the span is provided with roller-bearings at one end. About 12,000 field-rivets were driven, all by hand. Excluding the time occupied in making the islands, the bridge was completed and opened for traffic in $7\frac{1}{2}$ months.

Pa Ku Ho Bridge.—Four miles east of Chinchou the railway crosses the Pa Ku Ho, near its junction with the Hsiao Ling Ho,

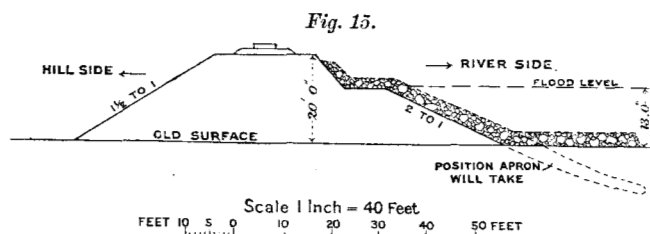
of which it is a tributary. The original design was for a bridge of four spans of 100 feet each. Early in May, 1900, the sinking of the caissons was commenced, these being the same size as those at Ta Ling Ho. Work was almost completed when the outbreak took place, five caissons having been sunk, four of them to a depth of 40 feet, and one to a depth of 30 feet, bottoming on dirty gravel. When the Russians took possession of the line, they completed the piers in concrete and erected girders. The costs given for this bridge in the Appendix are therefore for foundations only. This work is a typical example of air-sinking on a dry river-bed. The usual procedure was 3 days for sinking 9 feet; then 2 days for lifting the lock, erecting the concrete mould, and concreting; and 2 days for the concrete to set, before sinking was resumed. A siding was laid alongside the work, reducing handling to a minimum. The river is only 50 feet in width during the dry season, and the water-level was 1 foot below the ground-surface where sinking was commenced. The material sunk through was silt, sand, and sandy gravel. A sub-contractor undertook the sinking at 4 dollars per foot depth, which reduced the cost of excavation to 2·20 dollars per 100 cubic feet, as compared with 7·30 dollars with time-labour for the more difficult work at Shuang Tai Tzu. The sinking proceeded steadily, and the other work kept pace with it, greatly reducing the cost. The deadening effect of time-work is well illustrated by the costs for the Shuang Tai Tzu bridge; there, however, it was unavoidable. Since 1900, wages have risen 25 to 33 per cent., which would increase the cost from £1 9s. 10d. to, say, £1 18s. 6d. per 100 cubic feet, at the present time. This is probably cheaper than any other method of sinking, and has the great advantage that all concreting, except that in the chamber, is done in the open air, and no concrete is deposited under water, an operation which always leads to great expense, as extra cement has to be used to allow for loss. The strata passed through can also be examined and definite knowledge of the nature of the bottom obtained, often saving further sinking. If it is evident from the appearance of the foundation that no scouring has occurred for some thousands of years, it is obviously unnecessary to sink farther. Also, when rock is met with, removal of the rotten surface, or adjustment of the slope by means of divers is a very unsatisfactory operation.

Rainfall and Floods.—The total rainfall in North China for one year is small, but practically the whole of it occurs in July and August, as is shown by the record prepared by the Harbour Master at Yingkow, given in the Appendix. In 1903, July was a com-

paratively dry month, but August was very wet, and on 28 August all the large rivers were roaring torrents and most of them overflowed their banks and flooded the country on either side. At several bridges the water was nearly up to the girders, but, except at one bridge 2 miles east of Ta Ling Ho, no damage was done to the permanent work. The damaged bridge is in the centre of ground lying below the level of the Ta Ling Ho. The embankment is about 10 feet in height, and the water rose to the top of it, but fortunately the ends of the bridge (a single 20-foot span) were washed out, and relief was thus obtained before the flood rose higher. The gap thus made was 150 feet in length, and the bottom was scoured out to a depth of 20 feet. A section along this gap gives an area of twenty times that provided by the bridge. The abutments are founded on 24-foot piles, which, with only 4 feet of their length remaining in the bottom, kept the bridge in perfect line and level. A diversion was started on 1 September, as soon as the Ta Ling Ho could be crossed, and was opened to traffic on 5 September. As this was the largest flood ever known to have occurred on the Ta Ling Ho, it did not appear justifiable to go to the expense of increasing the opening, and the gap has therefore been filled in, the ends being pitched to confine any future break. The diversion earthwork is left, so that trains can be quickly got round the bridge should it be washed out again. The flood at this point lasted only 12 hours. On the plains there was considerable danger from the wind which accompanied the rain. Whenever the water attained a depth of 2 or 3 feet and no crops were standing, the waves cut into the soft earth of the bank so much that it was only by throwing down the track-ballast that damage to the bank was stopped. Stone has now been placed on the slopes to protect them from waves, wherever, owing to marshy or salt ground, crops are not grown. The almost universal crop of millet, the stalks of which reach a height of 10 feet to 12 feet, prevents the formation of waves. The water drained off in 2 days to a safe level, and in 3 or 4 days had almost disappeared, with the exception of pools. Near Kou Pang Tzu there is a river which, starting from the hills, traverses the plain for a distance of 15 miles, gradually widening out to 500 feet in width and about 8 feet in depth. In the dry season the quantity of water flowing is very small. In a distance of 2 miles the river course gradually contracts to about 15 feet in width, and when the floods come the water overflows all along this length and runs over the plain to the sea. In the vicinity of this and other overflowing rivers, after a heavy rainfall, mud and silt are deposited on the fields to a depth

of 2 inches to 6 inches, and, assuming that a serious flood occurs every 5 years, the surface is rising in places at the rate of $\frac{1}{2}$ inch per annum. Trees have the appearance of being covered up, and houses which, in the lifetime of old men now living, were built 2 feet above the ground, are now level with the surface. A pit was sunk at one of these places, and the layers deposited by successive floods, and even plough-marks, were distinctly seen.

Hsiao Ling Ho Embankment.—Five miles from Chinchou the railway passes through a gap in the hills, which is also occupied by the Hsiao Ling Ho river. The river comes right up to the edge of the hill-slope, by which its course is bent round through an angle of nearly 90 degrees. In winter the channel is small, leaving the greater part of the bed dry, but after heavy rain the water rises 12 feet and extends to a width of 2,000 feet. Following the contour of the hill, so as to keep out of the river-bed, would have involved reverse-curves of 1,500 feet radius, in heavy



rock-cuttings, and a tunnel 800 feet in length. Besides introducing sharp curves in an otherwise easy line this would have been expensive, and it was therefore decided to run the railway straight on across the bend of the river, with heavy pitching on the embankment. The river-bank and railway stand in relation to each other approximately as an arc of a circle to the chord; the total length of the protected bank is 5,000 feet, and the greatest width of the encroachment on the river is 300 feet. The embankment was made 21 feet in height, with a 1-to-1 $\frac{1}{2}$ slope on the inside and a 2-to-1 slope on the river-side, broken by a bench for the tramway for conveying materials, etc. (Fig. 15). The earth-work was done in the spring of 1900. The apron, 30 feet in width and 3 feet in thickness, was started in the winter of 1899–1900. Quarries were opened in the face of the hill, and sidings were laid along the apron. Large rough stones weighing about 1 ton were used, placed close together, the spaces between them being filled with smaller stones. The largest stones, some of which

weigh 2 tons, were placed along the toe. As the bank was completed, the pitching of the slope was laid in the same manner as for the apron, but of lighter stones, and was carried up to 13 feet above the river-bottom. This part of the work was completed in June, 1900, in time for the rainy season. In 1903, when work was resumed, the pitching was continued up to formation-level. In the floods of 1903 the water was 12 feet in depth, but no damage was done to any part of the work. The apron was scoured out a little, but so far it has not sunk more than 3 feet. In future floods it may gradually sink down to about 10 feet, which is about the limit of scour at the side of the river. Then it will remain a permanent protection to the bank. Any gaps that may occur in the process of sinking will be filled by the reserve of stone on the top slope. To let out the water from the cut-off bend of the river an 8-foot arch-culvert has been made, of concrete on piles; the wing-walls on the river-side curve down-stream, and specially heavy pitching is placed in the line of the culvert.

Sunk Tracks.—East of Kou Pang Tzu station, where the railway-bank is low, the track has been lowered to the ground-level for a length of 500 feet, at the end of which it resumes the ordinary formation-level. Pitching has been placed along both sides of the track, and in years of exceptional floods the water will flow over the track to a depth of about 1 foot. There are several of these sunk tracks on the system. In years of great floods, when ordinary channels overflow, a considerable quantity of water is inevitably held up by the railway-bank, in spite of the numerous bridges. No harm may result to the railway, but the villages near may suffer. These sunk tracks have been provided to let the water out; their cost is only a fraction of that of a bridge, which might have to be 1,000 feet or 2,000 feet in length to fulfil the same duty. The worst harm the water can do is to put out the engine-fires; this requires a depth of water of 18 inches above rail-level, which never occurs for more than a few hours per annum, on the average, when the stations are probably cut off from the roads, and few people are travelling. Sand or mud deposited on the rails is soon cleared off.

Stations.—The ordinary roadside stations have been placed about every 10 miles to facilitate crossing of trains. There are ten stations, all of which, except those at Kou Pang Tzu and Yingkow, are of the same type, consisting of a loop-line 1,300 feet in length with a short up-and-down siding for local traffic where required. The platforms are 400 feet in length, 20 feet in width, and 2 feet 3 inches in height above rail-level. The platform-walls are of

rubble masonry with a granite coping. The station-buildings are plain, with a booking- and telegraph-office in the main building, and living-rooms for the station staff in an annexe. At Kou Pang Tzu, the junction for the Hsin Min Tun line, a yard has been laid out (Fig. 16, Plate 6). The main passenger-platform is an island platform 1,200 feet in length and 75 feet in width. By means of a scissors-crossing the Yingkow trains can draw up at the south platform and the Hsin Min Tun trains at the north platform, so that passengers changing do not require to cross the tracks. There are four lines of tracks alongside each platform, for shunting goods-traffic; these can be added to at any time on the south side without pulling down platforms. For the local traffic a siding has been made on the north side next the town, with short spurs running off to accommodate the different kinds of trade. At the west end of the station the engine-shed, turntable, and water-tower have been placed, all inside a stone fence-wall. Here also are the repairing-shops for cars, etc., running on the Manchurian section of the railway. The engine-shed is a three-track shed, accommodating four engines on each track. The engine-pits and floor are of concrete, the walls of brick, and the roof of galvanized iron on trusses spanning the whole width. The smoke-trunks are continuous and are provided with chimneys splayed out at the junction with the smoke-trunk. The engine-shed, stores and office are in an annexe. The coal-yard and coal-stage are situated conveniently to the shed-tracks. The coal-yard is walled round to prevent theft, and as soon as the coal for the day is weighed the gates are locked. The water-tower, with a tank 20 feet in diameter and 12 feet in depth, is at the end of the coal-stage. Much trouble has been experienced with the water. The surface water is bad and limited in quantity, and an attempt has been made to tap the underground water by driving down tubes. The plant, brought by Japanese borers, was extremely simple. The boring-tool was a tin tube having a flap-valve at the bottom and open at the top. By "jumping" this tool on the bottom it became filled with mud; it was then drawn up and emptied. The tool was suspended on a rope of bamboo strips wound on a large drum made of old packing-cases, worked by a coolie walking on the inside. The whole outfit would not cost as much as £5, but with this simple contrivance men accustomed to the work have put down many bore-holes to a depth of several hundred feet. The bore-hole is afterwards lined with bamboo or iron pipe, and a tank is built around it. On account of the soft nature of the bottom at Kou Pang Tzu the pipes have become

choked, but work is still proceeding.¹ The workshop is a brick building, 300 feet by 50 feet, designed so as to form a second engine-shed when necessary. At present all the departments are gathered under one roof, but when business develops certain departments will be provided with separate buildings. The shop now contains two wheel-lathes, planing-, drilling- and slotting-machines, six small turning- and boring-lathes, and a cold saw. The smithy has eight fires and a 15-cwt. steam-hammer. There is a brass-foundry, but no iron castings are made. Power is obtained from a steam-engine. The turn-table gives access to a number of short sidings on which car-repairs are carried out, and a shed has been made to shelter the workmen from the winter winds. In the workshop there is room for two locomotives; the overhead travelling-crane is supported on a timber gantry, as the bricks are too soft to take much weight. Other buildings at Kou Pang Tzu are the engineer's department, store, staff quarters, and workmen's quarters, all of local brick with galvanized iron roofs, except the workmen's quarters, the roofs of which are built of lime and ash concrete.

Yingkow Station.—For the terminus at Yingkow, on the right bank of the Liao River, the ground had to be raised 7 feet, so as to be above flood-level (Fig. 17, Plate 6). The passenger-station has four tracks, with up-and-down platforms, and commodious buildings for the offices and staff quarters. Along the river-bank are the public goods-yard, and sidings with private yards to be leased to merchants as required. The wharf, which is 600 feet in length, is at the north end of the yard. The River Liao curves round so much that at one place two sections of the river are only about 2,000 feet apart, and when trade develops the railway will have a double frontage, as the ground has been taken from bank to bank. All the foreshore is being dressed off and protected with rubble. At the station, a three-track engine-shed for six engines, a turn-table, coal-stage, coal-yard, water-tower, and quarters for the staff have also been built. The water from the river is too salt for cleaning-purposes, and the railway is supplied from a pumping-station 10 miles back from Yingkow, where the railway is not far from the river. At low water the river-supply is fresh. The pumping-station is on the river-bank and contains two concrete tanks, 31 feet in diameter and 12 feet in depth. Adjacent to the tanks is the engine-house; a centrifugal pump draws from the river by a pipe under ice-level and delivers to the

¹ Since the Paper was written this difficulty has been overcome.

settling-tank. A reciprocating pump having a cylinder 6 inches in diameter and 12 inches stroke, pumps from the clear-water tank through an iron pipe 1,200 feet in length to a granite masonry water-tower at the railway, which carries a steel tank 20 feet in diameter and 12 feet in depth. Water is conveyed to Yingkow by goods-train by special cylindrical tank-cars, which are heated by a furnace in winter. Expensive signalling at stations has been avoided, as it is not required. The point-indicator, introduced by the Engineer-in-Chief, is quite sufficient protection for moderate speeds. A post consisting of an old rail is erected at the side of the points, and on it are pivoted two arms, one of which, 12 inches below the top, stands either horizontally or vertically, and the other, at the top of the post, is inclined 30 degrees on either side of the vertical position. These arms are so connected to the point-rods that when the pointsman sets the points by hand in the usual way the inclined arm shows which way the points are set, and the other arm, when horizontal, shows that the points are locked. The lock is in the middle of the track and to release it the pointsman has to stand between the rails; therefore, after being locked the points cannot be moved as long as a train is on them. At several stations on the railway, signal-posts and arms of the ordinary pattern are used. The points are worked by hand as usual, and the point-rod is slotted to control the signal-wire, which is worked from the platform. The signals are thus interlocked, at small outlay. Only at a large station, such as Tientsin, or at a junction, is the expense of a complete interlocking system, with all levers controlled from the cabin, justified. The signals adopted are the reverse of those in English practice, *i.e.*, the absence of a signal, due to the arm being carried away, indicates danger. "Line clear" is indicated by the horizontal position, and "danger" by the dropped position, thus saving all the weights which are required in English practice to make signals go automatically to danger if the rods or wires are broken or stolen. The name-posts at the stations have two arms, one on either side of the post at right-angles to the line. On these are the names of the station in English and in Russian, and on the post in vertical writing is the Chinese name.

Rolling-Stock.—The rolling-stock is of modern design; and the car-gauge of the Imperial Chinese Railways allows an outside width of 10 feet 4 inches over the steps, and 11 feet over the side-lamps. The height above rail-level to the ordinary roofs is 15 feet, with an additional 6 inches at the centre of the roof for chimneys, ventilators, etc. The whole of the passenger- and goods-stock

has been built at the railway-works; most of the tenders and two locomotives have also been built there, and additional locomotives are at present in hand. It is cheaper to buy material abroad and manufacture it in China, and extensive new shops have recently been completed at the locomotive headquarters at Tongshan.

Locomotives.—On the Peking-Tongku section, laid with 85-lb. rails and thirteen sleepers to the 30-foot rail, the passenger-engines are of the four-wheels-coupled type, with a bogie in front. The driving-wheels are 7 feet in diameter, and the cylinders 19 inches by 24 inches. The weight of the engine alone is 53 tons. For the goods-traffic, six-wheels-coupled engines, with a pony-truck, are employed, the driving-wheels being 5 feet in diameter, and the cylinders the same as those of the passenger-engines. On the 60-lb. rails of the Chinchou-Yingkow section the maximum axle-load is limited to 13 tons; the engines used on this track are illustrated in Figs. 18, Plate 6. The most numerous class have six wheels coupled, 4 feet 6 inches in diameter, and cylinders 17 inches by 24 inches, with a working-pressure of 180 pounds per square inch. These engines were designed by Mr. Kinder to embody the best points of British and American practice. The cylinders are outside, and all the parts are so arranged that they can be detached quickly by ordinary labour. On level sections of the line, or where the gradient is very slight, these engines take 130 loaded axles at 20 miles per hour. On passenger-service the speed is 30 to 40 miles per hour, which is all that is required at present. The railway is supplied with bituminous coal, about 75 per cent. of the value of the best English coal, at 12s. 3d. per ton delivered on cars at the pit at Tongshan. This is lower than the public rate, and in return, freight coal is carried to market at about $\frac{1}{3}$ d. per ton-mile.

Passenger-Cars.—The passenger-cars are all bogie-stock, and are fitted with central couplers. There are state-, buffet- and private cars, and first-, second-, and third-class ordinary cars. The state-cars are for Imperial and Viceregal use only, and are handsomely fitted. The buffet- and first-class cars are most comfortably arranged, but there is a commendable absence of gilding and useless dust-catching upholstery, which are quite out of place in China. The buffet-cars are 56 feet in length of body, and 63 feet in length over all, and the first-class corridor-cars are only slightly smaller. These cars are heated and lighted from the 57-foot brake- and mail-vans, which contain a compartment for boiler, dynamo and heater (Figs. 18, Plate 6). The second-class cars are 57 feet in length over the couplers, and of the same

external construction as the first-class cars, but inside they are fitted with plain wooden seats. The third-class cars are the result of practical experiment; they are open from end to end, are lightly roofed over, and have two large side doors. A Chinaman does not like to lose sight of his baggage, and with his bundles beside him is much happier in these cars than under "civilized" influence; indeed in summer many prefer to travel in the open trucks. The underframes of all these cars are of steel, and the bodies of wood. Except the third-class cars, all have end doors only.

Goods Stock.—Except the 10-ton coal-cars, all the goods-stock is of the bogie-type, and of 20 tons to 30 tons capacity; it comprises flat, low- and high-side cars, and covered cars. The outline dimensions are shown in Figs. 18, Plate 6. All iron-work about these cars is of the ordinary sections, no stampings or flange-work being permitted. The most recent cars have rolled joist underframes, slit along the centre, with the bottom part pulled down to form a fish-bellied girder, thus saving much work, as well as truss-rods, etc. All parts are substantially made and strong, to suit the conditions under which they work. Only the very best material has been used for wheels and axles, and stringent tests are applied. A Table of the rolling-stock in use on the line is given in the Appendix.

Traffic Working.—The traffic headquarters are at Tientsin, and the system adopted on older sections of the line will be extended to the Yingkow section. The rates for passenger-traffic are:—first-class, 6 cents (1.2*d.*); second-class, 4 cents (0.8*d.*); third-class, 2 cents (0.4*d.*) per passenger-mile. For specially large numbers, cheaper rates are allowed; for example, large numbers of men travel in the spring and autumn between Tientsin and Yingkow, to work in Manchuria, and these men are carried in full car-loads 385 miles at a rate which is equal to 1*d.* for 12 miles. Comfortable private cars, arranged with a kitchen, servants' and sleeping accommodation, are available for those requiring them, and dining-cars are run between Peking and Shan Hai Kuan. Between Shan Hai Kuan and Newchwang the number of foreign passengers is very small, but dining-cars will soon be run on that section also, as the increasing popularity of the Siberian route will bring more travellers over the line to Peking. In addition to the purely local stock, the dining-cars of the Wagon Lit will run between Newchwang and Peking twice a week, in connection with the mail-trains from Europe. Two rates for freight are in operation: (1) by the picul (133 lbs.); and (2) by the car. The result is that merchants hire a car, and put into it whatever

they please, provided the capacity is not exceeded, and the great bulk of the traffic is in full car-loads. Parcels may be sent by Express agency, or at ordinary parcel rates. Excluding dangerous goods, the rates per car-mile for full car-loads are:—for first-class goods, 5 cents (*1d.*); second-class $3\frac{1}{2}$ cents ($\frac{3}{4}d.$); third-class, $1\frac{3}{4}$ cent ($\frac{1}{8}d.$). First-class goods include general merchandise and manufactured articles; second-class, agricultural products and flour, timber, salt, wool, etc.; third-class, coal, lime, stone, etc. For special large shipments cheaper rates prevail, according to circumstances. The railway is worked on short and busy sections by the electric tablet, and electric staff block-systems, and on the less-developed portions of the line, where the distance between stations is considerable, by the ordinary train-staff and links. Under the ordinary staff, to prevent mistakes a double telegraphic form of enquiry and answer is used when it is necessary to suspend the ordinary staff working, and to issue a "line clear" form in lieu of staff; and this can be done only by the traffic-inspector of the district. Under these systems the traffic on a long single line is worked with regularity and great safety.

Quarries, etc.—Quarries (of chlorite schist) were opened at Tzu Chin Shan, 5 miles from Chinchow, a small quarry at Tsu Lai Pei, close to Ta Ling Ho, and two quarries (one of rhyolite and the other of granite) at Shih Shan Chan. Others (of limestone and quartzite schist), on the Hsin Min Tun line, also supplied a large quantity of the ballast and rubble, as well as lime. From the granite quarry at Shih Shan Chan all cut stone and building rubble was obtained, the other quarry at that place supplying track-ballast, concrete-ballast, and rubble for pitching and walling. Each quarry was let to a separate contractor, who was supplied with tools, gunpowder, etc., at cost price. Close supervision was required in order to prevent them working all the soft surface-stone and leaving the hard material. All stone was measured in the railway-cars, and costs, including loading, were—

For track ballast	$6\frac{1}{2}d.$	to	9d. per cubic yard.
„ concrete „	1s. $0\frac{3}{4}d.$	„	1s. $6\frac{1}{2}d.$ per cubic yard.
„ rubble „	8d.	„	1s. 2d. per cubic yard.

according to the quarry from which the material was obtained. The range of price is considerable, as at some quarries the siding could be laid right along the quarry-face, whereas at others the stone had to be carted some distance. Cut granite, 2 feet by 1 foot, cost $4\cdot4d.$ per lineal foot for the rough material, and $6\cdot4d.$ per lineal foot for the dressed stone. The corresponding prices

for platform-coping, 2 feet by 8 inches, were 3·6*d.* and 5·6*d.* per lineal foot. Special stones, such as window-sills, etc., were paid for at higher rates. The dressed stone was only roughly dressed, and required more work to be done on it before being used. Coal was supplied to the lime-burners at cost price, and they delivered the lime into the railway-cars at 6*s.* 1*d.* to 8*s.* 9*d.* per ton, according to circumstances; they never quite gave up hope of passing off whitewashed stones for lime, and this generally led to modifications in their bills. Bricks of good quality could not be obtained, as there was no good clay in the district. Contracts were let, however, and native kilns were put up at Kou Pang Tzu and Tien Chuang Tai, where some 5 millions to 6 millions of the ordinary soft native bricks were made for station-buildings, etc. The Chinese improve the quality and weathering properties of these bricks by allowing water to soak through the top of the kiln for several days after the burning is finished. The water is converted into steam by the heat of the bricks, which are changed in colour from red to grey. The price paid for bricks was 10*s.* 6*d.* per 1,000, coal being supplied to the contractors at cost price.

Administration.—The whole of the work involved in constructing this extension was done by the Engineering Department of the Railway. Before the Boxer outbreak there were two district engineers and seven assistants; but since that time there have been only one district engineer, two resident engineers, and two Chinese cadet engineers. The last-mentioned are trained engineering students, have been on the railway for many years, and are now very useful assistants. Chinese foremen were employed throughout, except for rail-laying, for which work two Europeans were employed. The former had under them gangers, who employed their own men. These gangers are really contractors for labour of the class to which they themselves belong, and draw all the money due to their gangs. The engineers had Chinese clerks, generally two in each office, who kept all the accounts of the section in English. The workmen, when sympathetically dealt with, work very well. If they have many tricks and perverse ways, which often sorely try the patience of the engineers, they, on the other hand, do not drink, or go on strike without reason, and are of a cheerful disposition. Should they threaten an engineer, he has either in some way, probably unknown to himself, dealt unfairly with them, or they think he has done so, until matters are explained. They were paid monthly, and do not require an advance every week, affording, in this respect, an example to British navvies.

Wages.—The following were the rates of wages paid—

	Per Month.					
	£	s.	d.	£	s.	d.
Office clerks	1	15	0	to	4	7 6
Foremen	1	6	0	to	4	7 6
Fitters and Smiths	1	6	0	to	2	12 6
Helpers	0	16	0			..
Carpenters and Masons	0	16	0			..
Coolies.	0	12	6	to	0	16 0

{sometimes
more.

{southerners,
up to £8 15s.

The Imperial Railway of North China is a Government line, the Directors-General being H.E. Yuan Shih Kai, Viceroy of Chihli, and H.E. Hu Yu Fen. The Directors are Taotai M. T. Liang and Mr. C. M. Lin. Previously to the Boxer outbreak the survey and preliminary work was done by Mr. J. Ginnell, and the construction-work was divided into two sections, namely, Chinchou—Shih Shan Chan, and Shih Shan Chan—Yingkow, under Mr. A. G. Cox, M. Inst. C.E., and Mr. J. G. Ginnell respectively, as District Engineers, their staff being Messrs. J. C. Martin, W. O. Leitch, J. H. E. Griffiths, J. E. Jackson, R. G. Gibson, E. C. A. Dunn, and A. Wright. After the outbreak the whole work was in charge of Mr. Cox as District Engineer, with the Authors as Resident Engineers, with Chinese assistants. The stores and bridge-shop at Shan Hai Kuan are managed by Mr. W. G. Howard. The Engineer-in-Chief of the Railway is Mr. C. W. Kinder, C.M.G., M. Inst. C.E., to whom, and to Mr. Cox, the Authors are indebted for the use of Reports and for permission to give the information contained in this Paper. The consulting engineers in London are Sir Benjamin Baker, K.C.B., Past-President Inst. C.E., for bridges, and Mr. C. P. Sandberg, M. Inst. C.E., for rails, wheels, and axles. Messrs. Whittall and Company, Limited, are the agents in London for the Railway.

The Paper is accompanied by seven sheets of illustrations, from which Plate 6 and the Figures in the text have been prepared, and by the following Appendix.

APPENDIX.

COSTS OF THE WORKS DESCRIBED.

The costs given in this Appendix are taken from the balanced accounts for the district; that is to say, the costs of every structure, when added up, balance the total amount charged by the chief accountant and chief store-keeper, and the detailed costs of any structure, when added up, balance the total as obtained from these accounts. General charges, where not stated separately, have been divided *pro rata*.

SHUANG TAI TZU BRIDGE.

	£	s.	d.
Open foundation excavation	25	15	0
Piling, seventy-six piles.	137	15	0
Concrete, 61,000 cubic feet	2,271	0	0
Masonry, 11,000 „ „	594	10	0
Islands	467	15	0
Sheathing of four steel caissons	1,200	10	0
Sinking (excavation), 56,000 cubic feet	2,097	10	0
60-foot girders (five)	1,772	0	0
200-foot girders (one)	3,384	10	0
Decking	146	10	0
Total cost of the bridge	12,097	15	0

Equivalent to £22 15s. per foot, or, for the 200-foot span only,
£27 10s. per foot.

SHUANG TAI TZU AND PA KU HO BRIDGES.

Cement Concrete:—	Per 100 Cubic Feet.					
	Shuang Tai Tzu.			Pa Ku Ho.		
	£	s.	d.	£	s.	d.
All labour	0	9	7	0	6	4
Ballast	0	5	5	0	4	6
Sand	0	0	2	0	0	6
Cement	2	12	0	2	12	10
Timber	0	3	0	0	2	10
General tools charge	0	2	1	0	1	0
„ labour „	0	2	1	0	3	2
Total	3	14	4	3	11	2

<i>Sinking :—</i>	Per 100 Cubic Feet.					
	Shuang Tai Tzu.			Pa Ku Ho.		
	£	s.	d.	£	s.	d.
Erecting plant	0	2	5	..		
Despatching plant	0	1	0	..		
Charge for use of plant	0	10	6	0	10	6
Engine-house wages	0	9	10	0	3	10
Labour outside the locks	0	7	0	0	1	9
„ inside „ „	0	12	9	0	3	10
Coal	0	17	8	0	5	3
Engine-house stores	0	2	1	0	0	6
Candles and rubber	0	1	9	0	0	4
General tools charge	0	2	8	0	2	1
„ supervision charge	0	7	2	0	1	9
Total	3	14	10	1	9	10

No share of the cost of the temporary bridge is included in the foregoing, as the data are incomplete.

<i>Girders :—</i>	£	s.	d.	
60-foot girders, 25 tons each .	1,747	15	0	= { £13 6s. per ton on cars
Erecting	24	10	0	= { at the bridge-works.
	1,772	5	0	outside shops.
200-foot girders, 158½ tons .	18	11	0	{ per ton on cars at the
				wharf.
Staging	1	3	7	per ton.
Erecting and riveting . .	0	17	6	„ „
Plant, tools and general } charges	0	14	3	„ „
Total	2	15	4	„ „

from arrival on cars to completion.

TA LING HO BRIDGE.

	£
All work below water-level	19,110
East abutment	140
Piers above water-level	3,226
Girders	16,357
Decking	720
Protection-works	288
Temporary bridge and diversion	2,210
General and miscellaneous work	161
Total	42,212

equal to £15 5s. 6d. per lineal foot, or £16 4s. 8d. per foot of opening.

<i>Detailed Cost of Work below Water-level :—</i>		Per 100 Cubic Feet.		
		£	s.	d.
Mechanics attending to air-plant		0	5	1
Engine- and winch-drivers and firemen		0	2	0
Cleaners, coal- and water-coolies		0	2	3
All labour in loading, moving, erecting and un- loading machinery, sheds, islands, etc. . . . }		0	12	3
Coolies sinking caissons and clearing spoil		0	6	6
„ blasting and cutting off tops of caissons . . .		0	0	4
All labour on concrete, including making moulds .		0	12	1
Stone-masons and helpers		0	1	3
Coal, at 7s. 8d. per ton		0	14	7
Cement, at 11s. 1d. per cask		1	17	3
Steel curb and working-chamber		0	9	5
Concrete ballast		0	6	1
Sand		0	0	10
Cut granite		0	0	4
Materials and stone (iron, timber, oil, etc.) . . .		0	8	11
Tool charges		0	1	9
Rent of plant		0	10	6
Superintendence, watching, and office charges . .		0	3	2
Total		6	14	7

<i>Detailed Cost of Girder-work (988 tons) :—</i>		Per Ton.		
		£	s.	d.
Girders on railway-cars		15	13	1
All labour at site		0	12	0
Plant, stores and tools		0	4	9
Superintendence, watching and office charges . .		0	1	4
Total		16	11	2

One contractor unloading girders pulled them over to the bridge and erected them for £10 10s. per span, or 5s. 6d. per ton. Another did all the riveting, using his own scaffolding, for 7s. per 100 rivets, or 5s. 1d. per ton. Both these men were supplied with timber, plant, tools, etc., free, but had to return them in a satisfactory condition.

<i>Detailed Cost of Portland-Cement Concrete (gauged 6, 3 and 1) :—</i>		Per 100 Cubic Feet.		
		£	s.	d.
All labour at the bridge site, including making moulds, etc. }		0	14	1
Ballast and sand		0	8	0
Cement		2	7	4
Plant, stores and tools		0	6	0
Superintendence, watching and office charges . .		0	1	7
		3	17	0

TEN YEARS' RAINFALL AT NEWCHWANG.

By permission of the Commissioner of Customs.

	1894		1895		1896		1897		1898	
	Inches.	Rainy Days.	Inches.	Rainy Days.	Inches.	Rainy Days.	Inches.	Rainy Days.	Inches.	Rainy Days.
January .	..	..	..	..	..	..	0·03	1	0·24	2
February .	..	..	0·51	3	..	..	..	..	0·15	2
March .	0·55	3	0·28	5	0·22	2	0·54	3	0·87	11
April .	1·40	5	1·02	6	1·06	4	2·69	8	0·45	4
May .	2·00	5	1·45	6	2·41	8	0·68	8	0·04	1
June .	5·45	9	1·59	4	2·36	8	1·15	6	3·80	10
July .	16·57	19	4·46	10	7·68	13	4·25	10	8·38	12
August .	5·79	5	7·12	14	4·99	6	4·69	16	1·94	4
September .	2·70	5	2·55	9	3·16	10	1·41	6	2·26	9
October .	0·34	4	0·50	4	1·89	7	0·75	2	..	..
November .	..	..	0·85	1	0·58	4	0·41	2	..	..
December .	0·65	1	0·39	3	0·30	1	0·09	1	..	..
	35·45	56	20·72	65	24·65	63	16·69	63	18·13	55

	1899		1900		1901		1902		1903	
	Inches.	Rainy Days.	Inches.	Rainy Days.	Inches.	Rainy Days.	Inches.	Rainy Days.	Inches.	Rainy Days.
January .	..	..	0·06	1	0·09	2	0·10	2	0·10	3
February .	0·10	1	0·15	3	..	..	0·06	1	0·05	1
March .	0·64	4	0·50	5	0·13	2	0·34	4	0·32	3
April .	0·11	3	1·68	6	0·65	3	0·80	6	0·73	5
May .	1·51	6	1·66	6	1·48	8	1·12	10	1·28	5
June .	2·88	10	0·89	5	1·69	5	0·99	7	2·32	6
July .	2·02	9	6·80	12	2·41	6	0·51	7	2·34	7
August .	3·86	10	4·24	11	18·55	14	2·40	13	22·82	11
September .	1·92	4	4·46	9	1·04	4	2·28	8	2·38	7
October .	..	..	2·46	11	1·19	6	0·53	3	0·23	3
November .	..	..	2·23	7	0·35	2	1·12	7	0·51	3
December .	0·03	1	0·05	1	0·30	5	0·30	4	0·05	1
	13·07	48	25·18	77	27·28	57	10·55	72	33·13	55

At Kou Pang Tzu there were two falls of 7 inches each in 12 hours.

In general, not much snow falls, but in March 1904 there was a fall of 12 inches in one week, and the line was blocked at Ta Ling Ho for some time.

TEMPERATURE AT NEWCHWANG, NORTH CHINA, 1903.

By permission of the Commissioner of Customs.

Month.	Maximum.	Minimum.	Mean.
	°F.	°F.	°F.
January	46	3	15·0
February	48	1	23·7
March	58	18	36·0
April	75	33	52·0
May	82	40	61·2
June	85	52	68·8
July	93	57	77·4
August	93	65	78·0
September	82	51	67·7
October	75	24	51·0
November	64	11	33·8
December	47	1	20·5

Taken at the Custom House, Newchwang.

Range of temperature, 96° F.

The winter 1902-3 was mild. Generally the thermometer registers several degrees below zero on many nights in January and February. The lowest temperature in the winter 1903-4 was -12° F.

TABLE OF ROLLING-STOCK IN USE.

Locomotives	105
Passenger-cars	109
Brake-vans	92
10-ton four-wheel freight-cars	743
16-ton eight-wheel "	53
20-ton " "	1,201
24-ton " "	12
30-ton " "	101

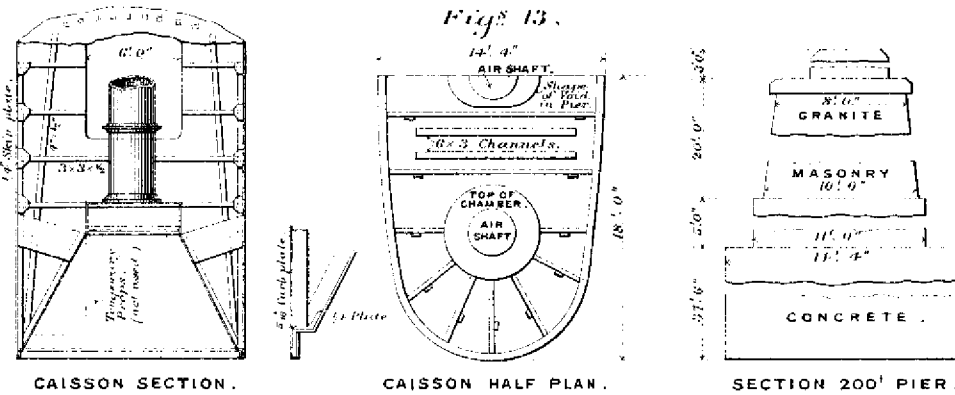
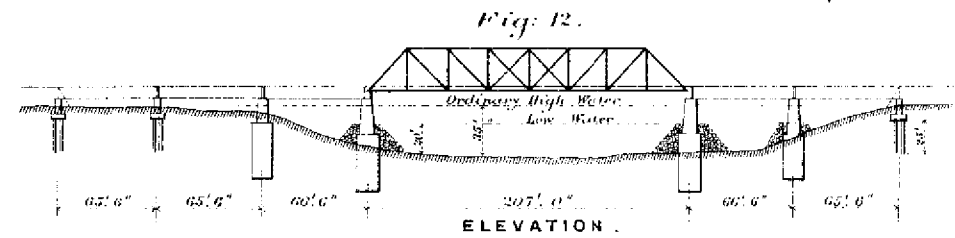
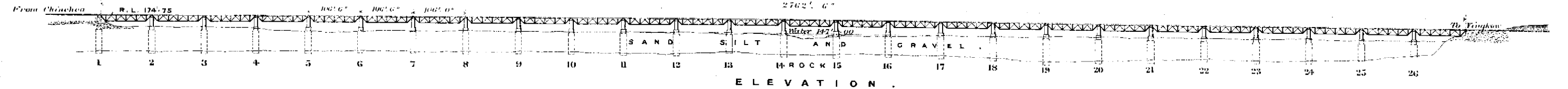
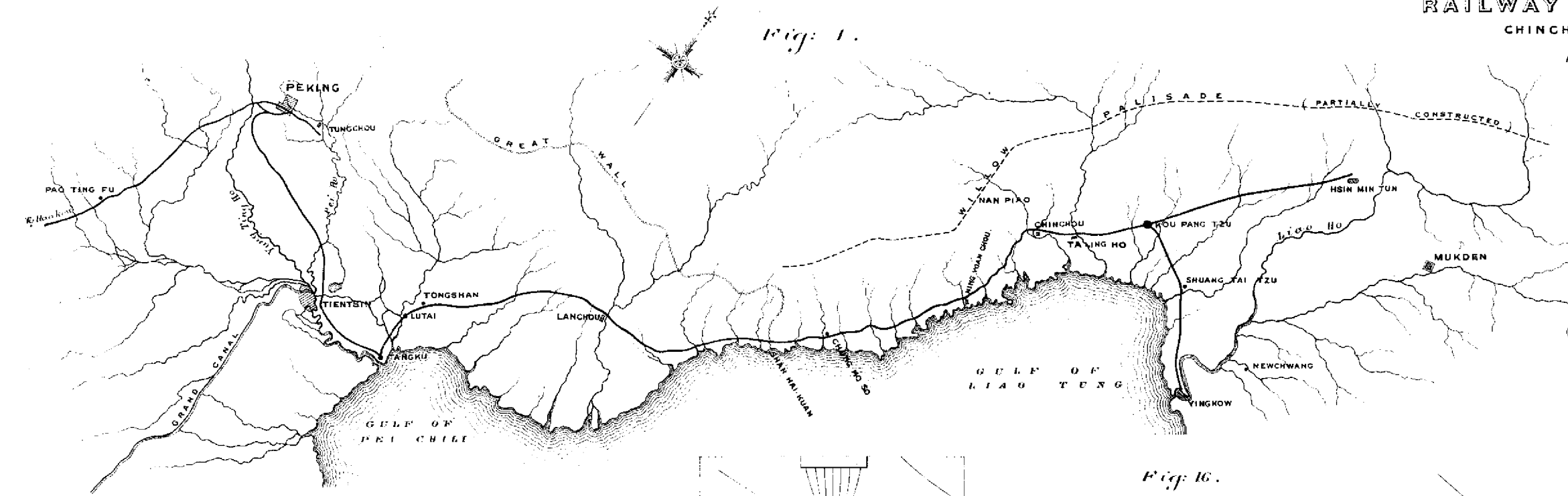
EXTRACT FROM ANNUAL REPORT, 1903.

Revenue for year ending 30 September, 1903 . .	407,550 ²
Expenditure " " " . .	199,500

The expenditure was roughly 50 per cent. of the revenue, but the lines east of Chinchou are not yet in full working order.

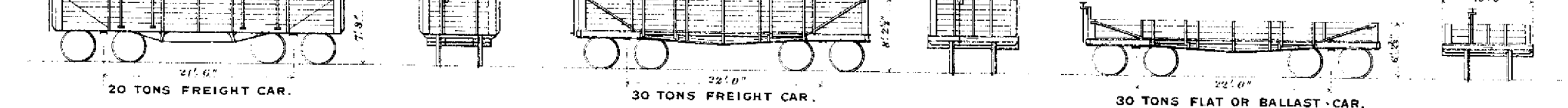
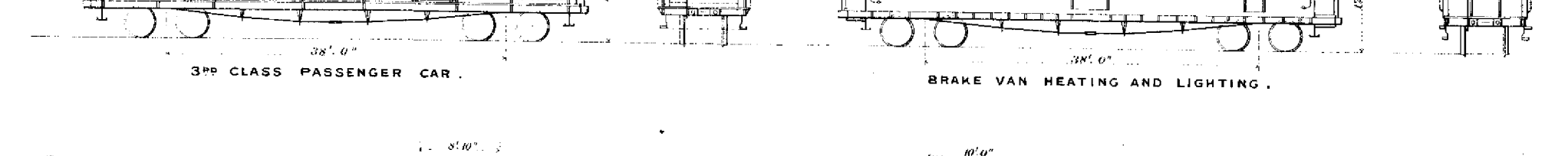
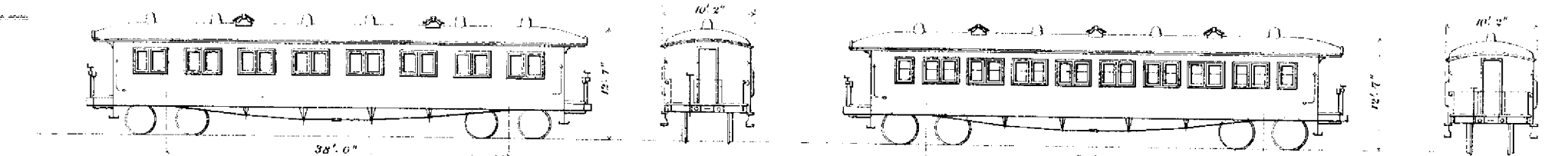
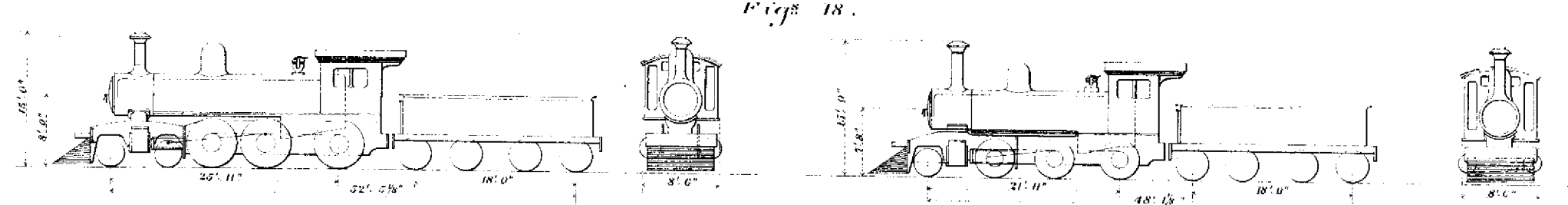
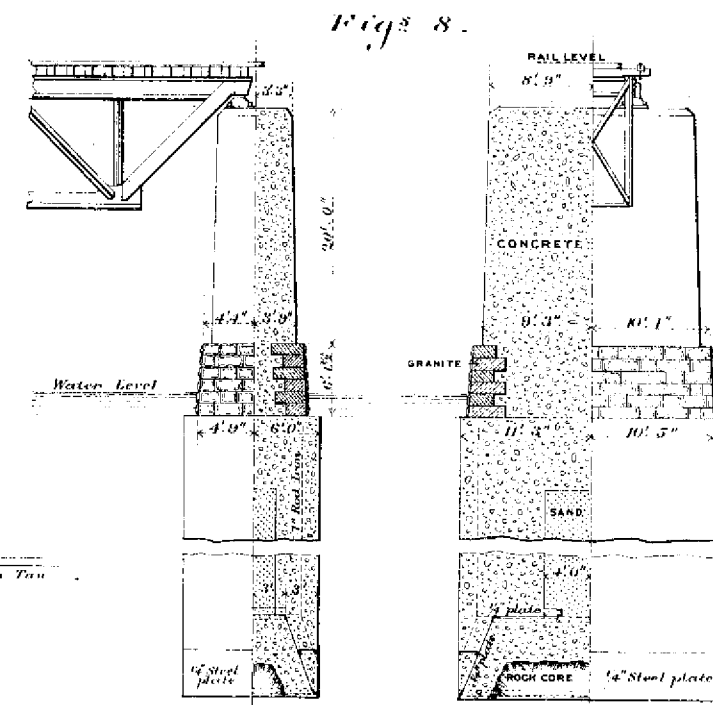
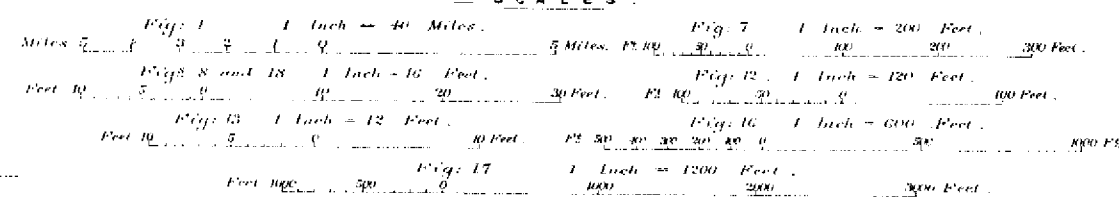
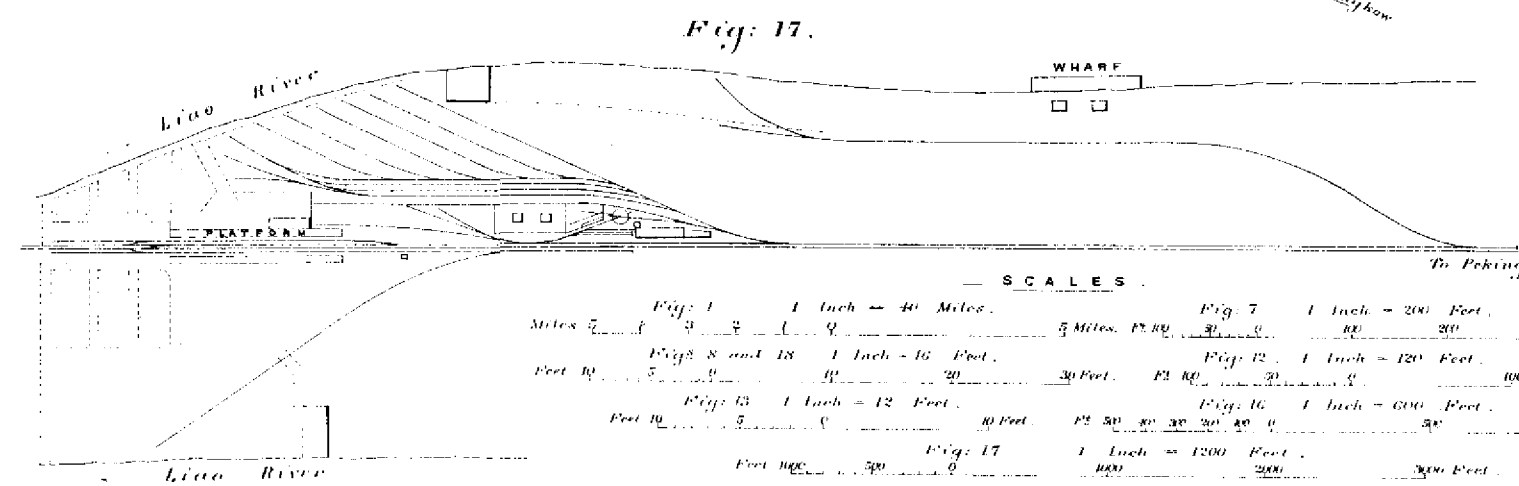
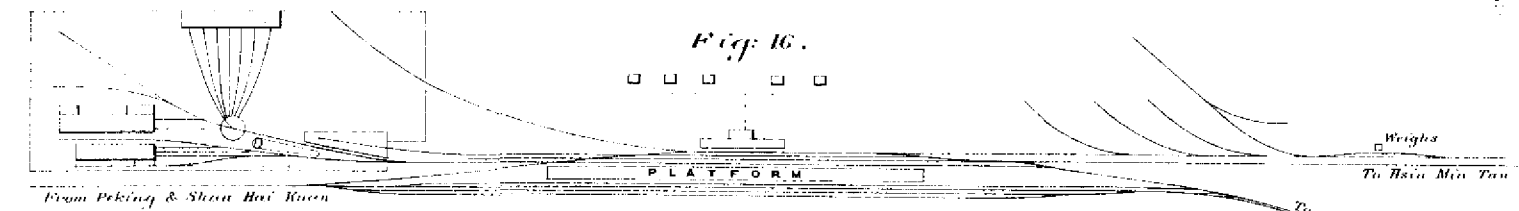
RAILWAY CONSTRUCTION IN NORTH CHINA CHINGCHOU-YINGKOW SECTION OF IMPERIAL RAILWAYS.

PLATE 6.



CAISSON SECTION. CAISSON HALF PLAN. SECTION 200' PIER.

J. R. RIGBY AND W. C. DEITCH.



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