to lightning, experience has proved that arresters must be installed at each transformer to give satisfactory protection. For protecting small pole type transformers, a cheap, but very effective, arrester is the so-called compression type, consisting of a hollow porcelain tube containing several multigap units with a series resistance of about 23 ohms. For outdoor substations or banks of larger transformers, a multi-gap graded shunt resistance arrester, mounted in asbestos-lined wooden boxes, for outdoor service, or a modified horn gap, such as the Burke arrester, can be used. The latter consists of a combination horn gap and triangular choke coil as shown in attached Fig. 3.

With this arrangement it is claimed that a much larger air gap can be used, which overcomes the objection to the simple horn gap arrester. With the Burke horn gap the usual values of air gap are:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Air Gap in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>11,000</td>
<td>1 1/2 - 1 3/4</td>
</tr>
<tr>
<td>22,000</td>
<td>2 - 2 1/2</td>
</tr>
<tr>
<td>33,000</td>
<td>2 3/4 - 3 1/4</td>
</tr>
</tbody>
</table>

No series resistance is used as is necessary in ordinary horn gap.

(To be Continued).

**Replacing a Railway Bridge.**

Renewal of the Maribyrnong (Saltwater) River Bridge, Victoria.

By F. K. Ealing.*

The total renewal of the girders of the Maribyrnong (formerly Saltwater) River bridge, between South Kensington and Footscray, Melbourne, has been recently completed, and the methods used in carrying out the work may be of some interest to engineers. Before dealing with the renewal itself, it will be well to mention something about the bridge which has been taken down, and which is clearly indicated on Figs. 1, 2, and 3, and on the photographic views. The old bridge consisted of three girders, one heavy middle span and two lighter outside ones; the total length being 216 feet, while the clear span between impost of abutments was 200 feet, so that the girders rested eight feet on the abutments each end. The end bearings of the girders were rather peculiar, consisting of two cast iron plates, four inches thick, one being bolted to the end of the girder, the other to the top of the bluestone impost. At the one end of each girder, these two cast iron plates rested directly over each other; at the other end eighteen 4-inch wrought iron rollers were placed between them. The cast iron bedplates were eight feet long, and it was found that the outer end of the one bolted to the girder was not in contact with the lower bedplate at all, but was cocked up very noticeably, so that there must have been a concentration of load near the other end of the bedplate. And, as this came out flush with the front of the impost, the bluestone must have had a considerable load per square foot. Both cast iron and bluestone, however, appeared to be excellent material, and no cracks were found in either. At the roller ends, the rollers had gradually worked grooves about 3/4 in. deep in both top and bottom cast iron plates, and had evidently acted as rockers rather than rollers. The girders were of the box-girder type, with the cellular top boom, introduced by Fairbairn, 14 ft. 6 in. high, and 3 ft. 6 in. and 4 ft. 7 in. wide respectively. They were erected in 1857, and were of iron. It is not often that one gets a chance of testing iron exposed to almost continuous, varying loads for nearly sixty years, so a few tests made with the material from this bridge may be somewhat novel. These show:

Plates of girders, average 20.9 tons a sq. inch.
Elongation, average 0.57 per cent.
Crossgirders, average 10.6 tons a sq. inch.
Elongation, average 8.2 per cent.

The bridge had evidently been designed for much lighter rolling stock than was even used in Victoria fifteen years ago, and the result was more unit stress per square inch than was usual for iron. About nine years ago it was decided to assist the girders by placing temporary oiled trestles underneath, and this was done as shown in Figs. 1 and 3, one larger span being left near centre for the traffic of boats and barges up the river.

In 1911 it was determined to do away entirely with the old box-girder bridge, by replacing it with a modern lattice-girder bridge. It was decided to let the steelwork by contract, also the riveting up when bolted in position; but that all other work should be done by the Railway Department by day labour. The writer was placed in charge of the erection works in June, 1912. There were special reasons which made it necessary to exercise the utmost care in doing the work, the main one being that the bridge carried over 320 trains a day during ordinary traffic conditions. The stoppage of running over the bridge would have meant the cutting off of all the Victorian Railways traffic to the west of the Bendigo lines, and even these trains could have only got into Melbourne by the inadequate

*Engineer, Victorian Railways.
single Bendigo-Wallan line, so that the bridge probably takes nearly half of all the State railway traffic. No attempt was made to provide any temporary diversion; and, in addition to the total renewal of girders, the line at the bridge had to be lifted 5 ft. 3 in. during the progress of the works.

The arrangements under the bridge will first be noticed. The Oregon trestles had been standing seven years when I took charge, and the lower part—including the walings—had been subjected to the rise and fall of three feet of tide twice a day; the

and it was felt advisable to adopt an easy method of checking any subsidence without having to use a level. This was done by fixing four sets of sighting boards to each trestle—alternately white and black boards—and leveling them most carefully across the river before anything was touched above. Observations had to be taken after that twice a day, and these were put down on specially printed cards, marked “A,” “B,” “C,” and “D” respectively for each line of boards. The cards were kept in packets, so that the engineer-in-charge could tell, at a

walings and bottom of post being partly in air and partly in water daily, although they could hardly ever be dry. Still, I had nothing to guide me as to the effect of the sea water (the water is salt, owing to the nearness of Hobsons's Bay) on the Oregon timber under the circumstances mentioned, so I added some special supports to the trestles in order to assure the proper division of the loads to be taken on to the piles. As these had been put in under rather awkward conditions, it was doubtful what each pile would carry, when the weight would come on them after the cutting away of the centre girder,

glance, the subsidence of any part of each trestle at any given date. When the subsidence amounted to about 1/4 in., a thin, planed strip was tacked on to the board (painted the same color) and brought up to the original level. The biggest subsidence noted was 1/4 inches, and the wedges between trestles and superstructure were tightened up daily to provide for any sinking. The whole system worked perfectly. On one side of the river the ground opened out rather suddenly, between the abutment and the river-sheeting; but all movement was stopped by fixing shores between the waling of the sheeting and
the crossgirders of bridge, the shores having been kept in readiness for such an emergency. In preparation for the cutting away of the centre girder, a number of rolled steel joists had to be reeved in between the two trestles, and the crossgirders above, somewhat as indicated in Fig. 1.

Turning now to the superstructure, the most important thing was, naturally, the gantry required for carrying out the dismantling of the old work and the placing in position of the new work. The were placed two 5-ton travellers, made by Messrs. Johns and Waygood (described in the "Commonwealth Engineer," March, 1914), and they did good service in meeting every demand made on them in rather exigent circumstances. It will be noted that the rolled steel joist bearers project 10 feet each side of gantry. This was for the purpose of easily reev- ing in the rolled steel joists, between trestles and superstructure, already referred to, as the winch was simply run over to the projecting part of bearers.

intense traffic (over 320 trains on week days, and about 100 on Sundays) was the determining factor, and it was seen that, for all purposes, it would be necessary to provide a platform for the workers and the storage of material just above the limit of the minimum structure diagram, while the travellers must be placed well clear of the highest part of the lattice-girders. The gantry was then designed, and its details will be clear from Figs. 3 and 4. On the gantry itself, running the full length of the bridge, and from there it lifted the joists off the pontoon which brought them, and reeved them into position afterwards.

In order to be able to examine every part of the structure minutely after dark, a 3000 c.p. electric lighting system was installed. As there was so much Oregon timber in the trestling and packing, arrangements were made for efficient protection against fires.

The gantry and travellers being in position, the
July 1, 1914.

THE COMMONWEALTH ENGINEER

Heavy centre girder was cut out to a line just above the cross-girders; the work being done (for the first time in the Department), by means of oxy-acetylene plants, and the trial was successful. The part below the cross-girders was left intact, in order that it might form, with the cross-girders firmly riveted to it and to the side girders, a rigid platform for the work to be placed over it. This work was then proceeded with, and consisted of raising the lines, by placing them on frames of heavy Oregon timbers, laid on the existing decking of the bridge. As the raising of the lines could only be done between 1 a.m. and 8.30 a.m. on Sundays (when there was no passenger traffic), it had to be carried out in three lifts, until the full rise of 5ft. 3in. was attained. The cross-girders of the new bridge are 5 feet high, and 23ft. 4in. apart, so the Oregon framing had to be made in 20 feet lengths, leaving a passage between frames wide enough to get the cross-girders in, and to do the necessary riveting. Before the lifting was done, the roads had been brought close together, so as to be, finally, 13ft. 8in., centre to centre.

After all this had been accomplished, there was some block in the supply of the steelwork, and the work was closed down temporarily. The contractors, Meaphan Ferguson Pty. Ltd. laid out the whole of the girders most carefully in a paddock adjoining their works at Footscray, and the girders, bracing, etc., were bolted up in an upright position. Every piece was marked by distinctive letters and numbers. When all was ready for the Department to erect, we took most careful measurements as to levels (camber) and lengths, and transferred these carefully to the side girders of the old bridge; and it may here be remarked, in anticipation, that the whole of the members were bolted up again by us without the slightest hitch occurring. A proper scheme was then drawn out for the delivery of the different members of the lattice girders, etc., as they stood in the contractors' yard. On Sunday mornings the pieces wanted were supplied in trucks, and unloaded on the bridge, the quantity provided being just enough to keep going during the ensuing week to bolt them together. The general idea was
to fix the centre bay first—cross-girders, top and bottom flanges, verticals and diagonals, and top and bottom bracing—all complete—and when this was set, to work from there to the ends, finishing off with the setting of the rocker, and roller bearings. Everything worked most smoothly, although at times, when traffic was at its worst—trains following trains as rapidly as the block section would allow—it was not uncommon to see a member, 40 feet long, and weighing up to 7 tons, being held in position between two trains while these were crossing on the bridge. No accident or damage whatever happened to passengers or rolling stock; and there was no fatal accident among the large number of workmen who were most of the time almost in touch with passing trains, or working over the river in somewhat precarious positions.

After the girders, etc., had been bolted up, the contractors for the steel work erected a pneumatic riveting plant, and fixed about 12,000 rivets. The decking was then laid down and bolted, and the Oregon frames removed, after which the trains were allowed to pass over at 15 miles an hour, as it was not considered advisable to permit full-speed running while the men were still engaged in dismantling the girders and gantry. Full speed has been on now for over a month.

Other minor works, such as the raising of the embankments for over 1,200 feet in length, track-loading for the special purpose of slowing down trains before they reached the bridge, removing and relaying the big water mains, etc., also had to be done; but do not need special consideration.

The bridge is a good example of the change and progress in bridge building during the last 50 years. The old iron bridge was 14 ft. 6 in. high, and had 460 tons of metal in it; the new steel lattice bridge is 37 feet high, and weighs but 345 tons, yet the new structure will carry, with the same factor of safety, twice as much load as the old one.

Particulars of the girder work are given on Fig. 6, and the details will repay examination, while attention may be drawn to the novel method of fixing the stringers to the cross-girders.

As the cost of engineering work is often of advantage to the designing engineer, I give the particulars of the expenditure:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract for steelwork</td>
<td>£111.40</td>
</tr>
<tr>
<td>Charges for taking down old work</td>
<td></td>
</tr>
<tr>
<td>And putting in new</td>
<td></td>
</tr>
<tr>
<td>Permanent way work, outside bridge</td>
<td>£10,782</td>
</tr>
<tr>
<td>Total cost</td>
<td>£23,422</td>
</tr>
</tbody>
</table>

The girder work was designed by Mr. A. G. Goudy, under the direction of Mr. J. H. Fraser, Chief Engineer of Way & Works, Victorian Railways; while the successful carrying out of the removal of the old work, and the placing in position of the new girders were due, to a great extent, to the energy and skill of my assistant, Mr. G. S. Luttrell.

The report of Messrs. Merz and McLellan, electrical engineers to the London county council recommends the replacement of the existing stations by a central station; a high voltage three-phase primary distribution system at 50 cycles per second should be standardised for London as soon as possible. In this connection they also suggest a standard primary voltage should be at once adopted for all new high-pressure mains.

In connection with the Nihotupur, N.Z., reservoir scheme, the officials reported that the amount available for constructing the reservoir out of the Waterworks Extension and Improvement loan was £73,799. As the city engineer's estimate of the cost of the work was £120,000, it was necessary to provide for an additional £46,000. It was recommended that an annual appropriation of £6240 be made for five years from the surplus of the waterworks account in preference to raising a new loan, which would impose an annual charge of £2310 on account of interest and sinking fund, for 21 years.