The Woods-Gilbert
Rail Planer Co., Ltd.

Rail Planing Machines

Offices:
MELBOURNE: 31 Queen Street.
LONDON, W.C.: 2 & 3 Norfolk St., Strand.

The Woods-Gilbert
Rail Planer Co., Ltd.

Notes on the WOODS-GILBERT method of Treatment for Maintenance of Tramway and Railway Rails by:—

(1) *Grinding out corrugations.*

(2) *Dished and hammered joints.*

(3) *Milling out the groove.*

(4) *Cutting down the guard lip.*

Offices:—

31 Queen Street,
MELBOURNE.

2 & 3 Norfolk St., Strand,
LONDON, W.C.

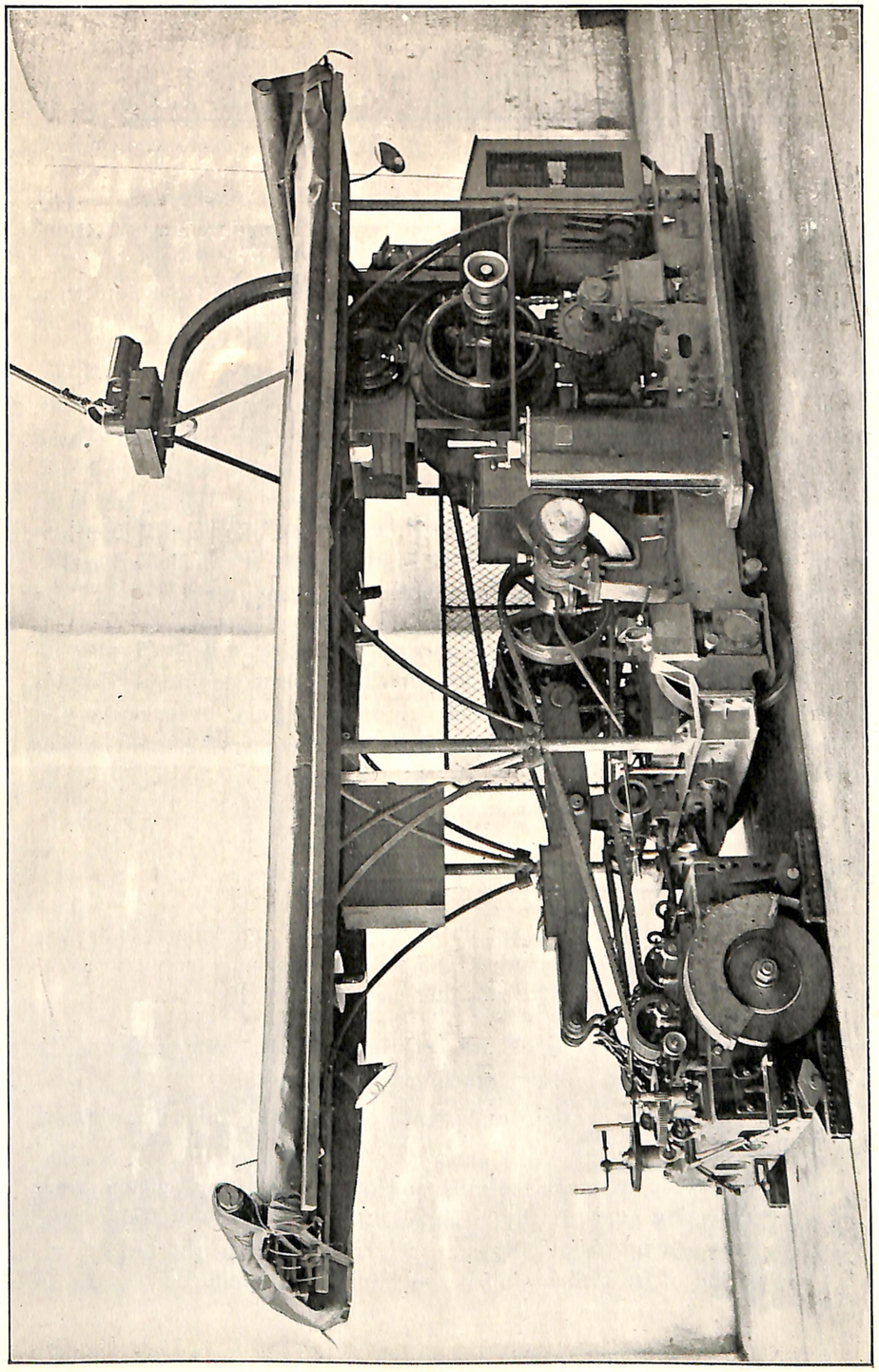
May, 1916.

INTRODUCTION.

THE wide development of Electric Traction throughout the Tramway Systems of the world has, to an eminent degree, met the demand for high speed traction; but it has brought with it problems connected with track maintenance, which constantly exercise the economic consideration of Tramway Engineers and Managers.

The comparatively short life of the rails; the varying ratio of wear on the tread and guard lip; the dishing at joints; and the setting up of corrugations, are conditions which obtain more or less on all tramway rails within a few years after they are put into active service.

It would appear obvious that some practical and economic method for the in situ treatment of rails were required, whereby the life of the rails would be prolonged, and the other defects remedied prior to the ultimate steps being taken of renewing the rails, with all the attendant cost, and disturbance of traffic and road bed.



Improved Double Headed Rail Grinding Machine, Electrically Driven—1916 Type.

Woods-Gilbert Rail Planer Co. Ltd.

FOR some years past the Woods-Gilbert Rail Planer Company has closely followed up the requirements connected with the maintenance of tramway rails. They have succeeded in working out methods of remodelling the rails, whereby a largely-increased life is given to them, and the defects at joints and corrugations are removed, giving a smooth-running track throughout, without any disturbance to rail or road-bed.

The Directors of the Company, after ascertaining the wide scope available for their patented machines, have expended large sums in constructing and perfecting the machines, and putting them into active service on tramway tracks. In addition to this, they have established a staff of engineers and mechanics specially skilled in the technical work of remodelling tramway rails. The Woods-Gilbert method of treatment of rail deformities is now widely recognised by Tramway and Railway Engineers.

The Company is in a position to enter into contracts with Municipalities, Governments, and Tramway Companies for the remodelling of the rails on tramways, and also for steam and electric railways; also to make the preliminary investigations and submit proposals for the carrying out of this important work.

REMODELLING OF TRAMWAY RAILS.

The method employed is by the use of a powerful and substantially constructed machine, fitted with grinding and milling attachments, operating on both rails simultaneously. The machine weighs up to 10 tons.

Two distinct classes of work are performed by the one machine, by adopting the grinding or milling attachment as required:—

1. Grinding out corrugations and dished joints, using 24in. dia. abrasive wheels.
2. Deepening the groove of the rails, and at the same time, cutting down the projecting guard lip by means of 12in. dia. rotary high steel cutters, thus giving about 50 per cent. increased life to the rail beyond the period of its ordinary life, also minimising accidents to vehicles

from the projecting lip, ensuring smooth running for the cars, and reducing maintenance charges on the rolling stock.

The deepening of the groove and guard lip is done by a milling trolley or adapter, attached to the tractor, in place of the grinding trolley.

The machines are accurately balanced to ensure a fine adjustment to the work.

The cost of treatment by the machines is governed by the condition of the rails. Quotations will be given for the work required after an inspection of the tracks has been made. The saving effected, however, is a very substantial one, compared to the heavy cost of rail renewals, and, in addition to the saving in capital cost of renewals, further economies are represented in reduced cost of track and car maintenance.

Contracts have been carried out by the Company in

Australia—

Melbourne Cable Tramways
Sydney Electric Tramways
Brisbane Electric Tramways
Adelaide Electric Tramways.

Great Britain—

Oldham, Ashton, and Hyde Electric Tramways
Isle of Thanet Electric Tramways
Cardiff Electric Tramways
Wigan Electric Tramways.
Bexley Urban District Council Tramways.

Other important contracts are in hand.

Corrugation.

The corrugation of rails is one of the most difficult and persistent problems tramway engineers have to contend with. The causes of corrugation are difficult to arrive at. Numerous committees of experts have closely studied the problem, and a vast amount of evidence and data relating to the phenomena has been published in Great Britain, Europe, and America, none of which is unanimous in arriving at a solution of the cause.—(Vide extracts from Interim Report on Rail Corrugation, appended.)

The injury to the permanent way caused by corrugations is a serious one; the bed of the track is pulverised and loosened by the continued pounding on the rails; water gets in and sets up trouble. The car wheels are affected by the uneven surface, requiring constant turning up in the workshop; the rolling-stock is impaired, and the noise and discomfiture to passengers is a serious trouble. Eventually the rails have to be taken out, and the tracks relaid at heavy expense.

Many improvised methods have been tried to keep down the corrugation trouble, such as using corundum rubbing blocks on the cars, and light grinding machines of various types. Experience shows that none of these methods have proved effective. A powerful machine, such as that designed by the Woods-Gilbert Company, with ample weight and rigidity, has proved highly efficient in coping with the trouble. The improved 1916 design weighs about 9 to 10 tons.

To obtain the best economic results, rails should be treated early, before corrugation becomes very pronounced. The cost of treatment is then lighter, and the wear on car wheels and injury to road bed is considerably reduced, while better running is ensured.

Capacity of Machine.

When surface grinding, the machine treats approximately 12,000 lineal feet of single track per month.

For milling work, 9000 lineal feet of single track per month.

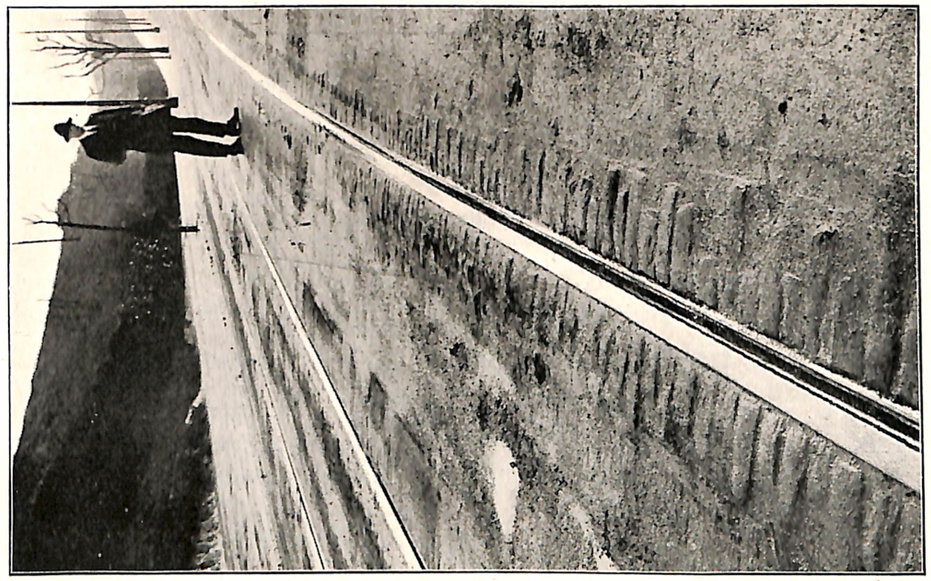
Mobility of Machine.

The machine has been designed with suitable under-gearing to enable it to be run along the tracks at up to 20 miles per hour (when not engaged in remodelling work), and by the use of transverse gearing can also be quickly removed from the track to allow cars to pass where there is a night service. The machine only requires three operators. The work is carried out at night, after the cars have stopped running, and the tracks are left clear in the morning for the cars at schedule time.

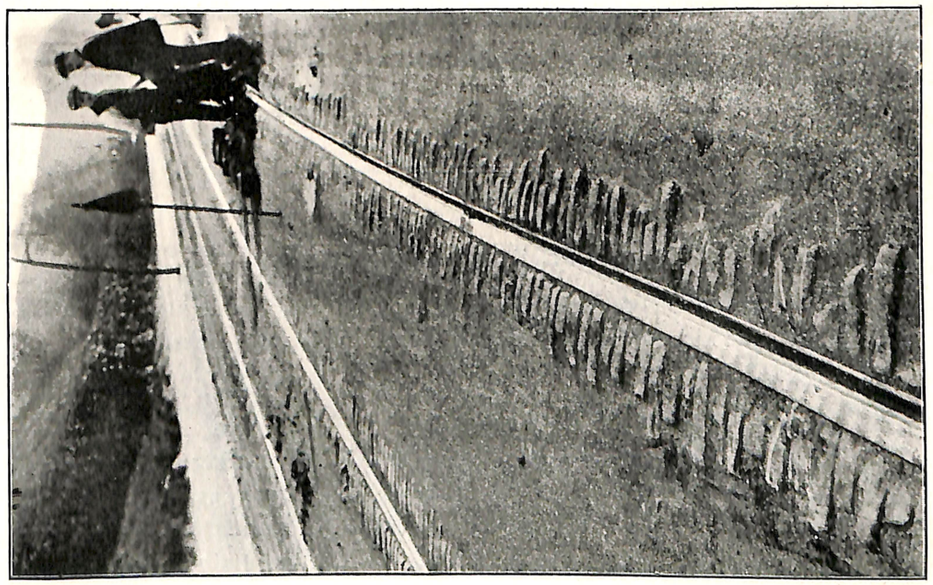
Gauge.

The Standard Machine will operate on 4ft. 8½in. gauge, but can also be adapted to other gauges.

Examples of Work in England by the Woods-Gilbert Coy's Process.



After Treatment.



Before Treatment.

MELBOURNE TRAMWAYS.

G. S. DUNCAN, M. Inst. C.E.
Consulting Engineer,
The Melbourne Tramway & Omnibus Co. Limited.

32 Victoria Street,
Westminster, S.W.,
28th October, 1912.

Remodelling of Melbourne Tramway Rails.

THIS IS TO CERTIFY that the Woods-Gilbert Rail Planer Company Limited remodelled over 90 miles of rail (45 miles single track), on the Melbourne Cable Tramways.

The work was carried out under a Contract, which was executed on the 18th August, 1909, between the Melbourne Tramway and Omnibus Company Limited and the Woods-Gilbert Rail Planer Company Limited.

The Contract stipulated, *inter alia*, that the cutting and reshaping of the tramway rails should be carried out *in situ*, and without damage to the Tramway Company's property or the public; it also provided that I should act as the Engineer in supervising the work.

The work of cutting the rails, which comprised the milling out of the grooves and the cutting down of the guard lip, was carried out in a highly satisfactory manner. The remodelling of the Melbourne Tramway rails has proved satisfactory to the Tramway Company, as well as to the public generally.

GEORGE S. DUNCAN.

Remarks by Chairman of Melbourne Tramways.

Extract from the remarks of the Chairman and Managing Director, at the Annual Meeting of Shareholders of the Company on Tuesday, 24th September, 1912:—

"During the year, the tracks and buildings, rolling stock and plant, have been kept in their usual good order. **The recutting of the rails was finished in February last. This work was very satisfactorily performed, and has much improved the smooth running of the cars, and lessens the expenditure on the cars and track for maintenance.**"

THE BRISBANE TRAMWAYS CO. LTD.

51 Countess Street,
Brisbane,
Sept. 16th, 1912.

C. E. Bernays, Esq.,
45 Adelaide Street,
Brisbane.

Dear Sir,—

Mr. Eunson, who was in charge of work here for the Woods-Gilbert Company, of Melbourne, asked if we would write stating the work that had been done for us. We have pleasure in stating that the total work done was as follows:—

A total of 6775 feet was cut out on the tread of the rail, and 2975 feet cut on the groove of the rail.

The work was done in a most thorough and satisfactory manner, and has effected a very decided improvement in the comfort of the travelling public, and from a maintenance point of view in eliminating the hammering that our equipments were subjected to under former conditions.

Yours truly,
(Signed) N. G. STEVENS,
Acting Manager.

ADELAIDE MUNICIPAL TRAMWAYS TRUST

CONTRACT.

The preliminary contract with the Adelaide Tramways Trust, November, 1915-January, 1916, consisted of treating 40,757 lineal feet of rail, and was carried through by one of the improved type of machines. The work was completed in 44 nights' actual working, average number of feet per night 926.13 over the whole mileage treated. From January 3rd to 13th, 1916, 10 nights' working, under normal conditions, totalled 11,989 lineal feet, averaging 1198.9 feet per night of about 5½ hours. The highest single night's run was 1530 feet. The work gave complete satisfaction to the Tramway Authorities.

Machines are employed continuously on the Sydney and Adelaide Tramways.

N.S.W. GOVERNMENT TRAMWAYS.

Engineer for Tramways Office, 61 Hunter Street,
Sydney, 25th September, 1914.

Gentlemen,—

THIS IS TO CERTIFY that the Woods-Gilbert Rail Planer Co. Ltd. has been treating rail corrugations and joints on the Sydney Tramway System for some months past, and the work has been carried out in a very satisfactory manner.

Yours faithfully,
(Sgd.) G. R. COWDERY.

The Woods-Gilbert Rail Planer Co. Ltd.,
31 Queen Street,
Melbourne.

WOODS-GILBERT RAIL PLANER CO. LTD.

At a meeting of members of the Electrical Association of Australia, Victorian Section, held on the 15th July, 1915, the Victorian President, Mr. F. A. McCarty, the well-known tramway engineer, in his address on "Electric Tramway Construction," when referring to the corrugation problem, said:—

> "The only obvious practical way of overcoming corrugations at the present time is by grinding the surface of the rail by the Woods-Gilbert machine, which is an Australian invention, and specially designed to do grinding and milling of rails in the permanent way. . . . The Company that controls this machine does not claim that it is a preventive of corrugation, but the rail can be ground true again."

OLDHAM CONTRACT (near Manchester.)

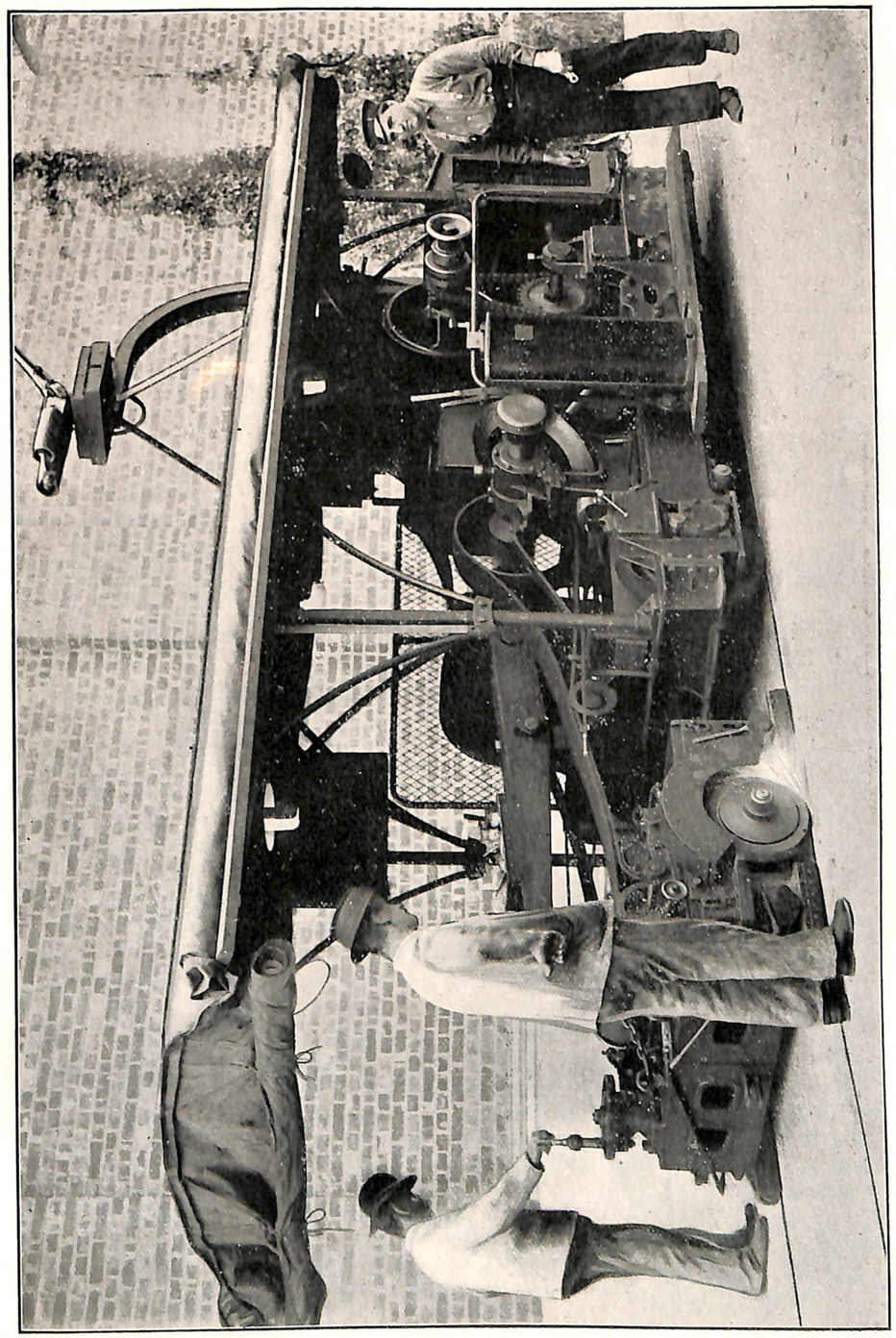
Electrical Federation Offices,
Kingsway,
London, W.C.,
29th October, 1912.

The Manager,
The Woods-Gilbert Rail Planer Co. Ltd.

Dear Sirs,—

We have pleasure in stating that the work of deepening the groove of the rails of our tramway, undertaken by your Company with the Woods-Gilbert Rail Planer, has been carried out to our complete satisfaction.

Yours faithfully,
THE OLDHAM, ASHTON & HYDE TRAMWAY LIMITED
(Signed) W. E. WOODROOFE,
Secretary.



Woods-Gilbert Machine Grinding Rails—1916 Type.

The following data, taken from reports, journals, and other publications giving the opinions of authorities on the problem of rail corrugation, will be of interest to Traction Engineers:—

EXTRACTS FROM THE

INTERIM REPORT

ON RAIL CORRUGATION.

Issued by The Municipal Tramways Association in England, in 1912. The Report covers the work of the Committee, comprising the leading tramway engineers in Great Britain and extends over a period extending back for six years.

The Corrugation Committee have held altogether 15 meetings. The Sub-Committee have held 30 meetings since they were appointed in February, 1911.

The following line of inquiry submitted by Mr. King was adopted:—
"Investigation of Rail Corrugation."

"As the result of many independent investigations and experiments, a number of causes of corrugation have been put forward. In view of the fact that no one cause has been proved with certainty to be a factor in the production of corrugation, it would probably be the wish of the Committee to investigate the whole of the stated causes.

"I would suggest that the Committee begin by considering several wide divisions, into which the question may be classed.

"Corrugation either exists initially in the rails or tyres, or is produced by the mutual action between these two, during the passage of the wheel. I would, therefore, propose the following broad classification of causes:—

"1. Exists initially in the rail itself.

"2. Exists initially in the tyre.

"3. Is produced by the mutual action of wheel and rail, which action must be one of, or a combination of, the following:—
"(a) By the ordinary rolling motion of the wheels owing to the rail not being hard enough to withstand the local rolling action.
"(b) By the wheels slipping.
"(c) By the wheels skidding.
"(d) By the radial slipping of wheels and axle.

"The causes which have been stated by many investigators:—Weak trucks, unsymmetrical gearing, unequal diameters, chattering

brakes, torsion of axles, springing road bed, etc., can produce corrugation only by one or more of the above stated actions between wheel and rail. If it can be proved what is the actual action between wheel and rail which produces corrugation, say, for example, 'skidding,' then the scope of the further enquiry is narrowed down to the causes which produce skidding and their prevention.

"There is a very considerable weight of opinion which holds that corrugation exists initially in the rail itself. This appears to me to be a comparatively simple theory to prove or disprove, and I would suggest that the first enquiries of the Committee be devoted to this point, as its disposal would clear the way to investigating the others.

"The proposal of the Committee to lay down similar test places on each system should give very valuable results if the conditions are kept as much as possible alike, and the observations carefully taken. It would seem to be of some value to have the test places put down as nearly at the same time as possible.

"When the returns begin to come in it would be very valuable to have at hand a collection of standard data relating to each system, so that comparisons and deductions may be made from the results."

One of the first actions of the Committee was to prepare and issue a List of Queries to the members of the Association, so as to collect data on corrugation and the various factors, such as rolling-stock, permanent way, etc., concerned in its production.

A schedule of Proposed Experiments to give information on points on which there was no authoritative decision was prepared by Mr. King, and adopted by the Committee, and some or all of these were carried out at Bradford, Dundee, Glasgow, London, Leeds, Manchester, and Sheffield.

Replies to Queries.

A List of Queries was sent out to the tramway systems in the latter part of 1909. The object of these was to elucidate several points:—

1. To get detailed information as to the occurrence and extent of corrugation
2. To find if there were any features of climate, rolling-stock, permanent way or operation, which were peculiar to those systems which had little or no corrugation as compared with those which had extensive corrugation.
3. To get data of each system so that any peculiarity in connection with that system in regard to corrugation could be thoroughly investigated as to the conditions under which it occurred.

It was many months before the replies were returned, and, when these were to hand, the condensing and tabulation was undertaken by Mr. King. There were over 6000 separate replies, and the work extended over several months.

The result of a very careful analysis did not reveal any striking characteristics peculiar to systems having corrugation. A very considerable clearing of the subject was, however, effected, and many theories were finally disposed of.

A general summary of the bearing of the Replies on Corrugation brings out the following rather interesting points:—

Generally those systems having little or no corrugation are more hilly than the average system.

Neither the annual rainfall nor general climatic conditions appear to have much effect on corrugation.

A number of systems replied that corrugation is less where the ordinary vehicular traffic is heavy, but this would appear to have a secondary effect in causing frequent stops and reducing speed of the cars, besides the actual wearing effect of other wheels on the rails.

PERMANENT WAY.

The tendency has been towards increasing the length of rails, but this does not appear to have had any effect in lessening corrugation.

The methods of making the joints vary greatly, but no deduction can be drawn from the replies as to the effect of the jointing on corrugation.

So far as the Replies to Queries go, they show that no one class of paving has more effect than another on corrugation.

The chemical composition and process of manufacture are important features, and will be dealt with later in the report.

The great majority of the replies show that corrugation is not found to be more frequent, nor to make an earlier appearance, on any particular type of rail, nor on the rails from any one maker.

The nature of the subsoil has frequently been stated to be an important factor in the production of corrugation, but the replies do not show this to be substantiated. Corrugation takes place where the track is on hard or on soft subsoil, and some systems claiming to have no corrugation are laid on soft subsoil and some on hard subsoil.

The methods of packing, concreting, and laying rails are very varied, but no one of the methods used has secured a track which will not corrugate.

The question of the effect of anchors is a difficult one, but the replies show that the most corrugated systems include those where the anchors are frequent, and also those where there are no anchors.

ROLLING-STOCK.

Probably one of the most interesting sections of the replies is that relating to the wheel, as in whatever manner corrugation is originated, this is the ultimate agent by which it is produced on the rail.

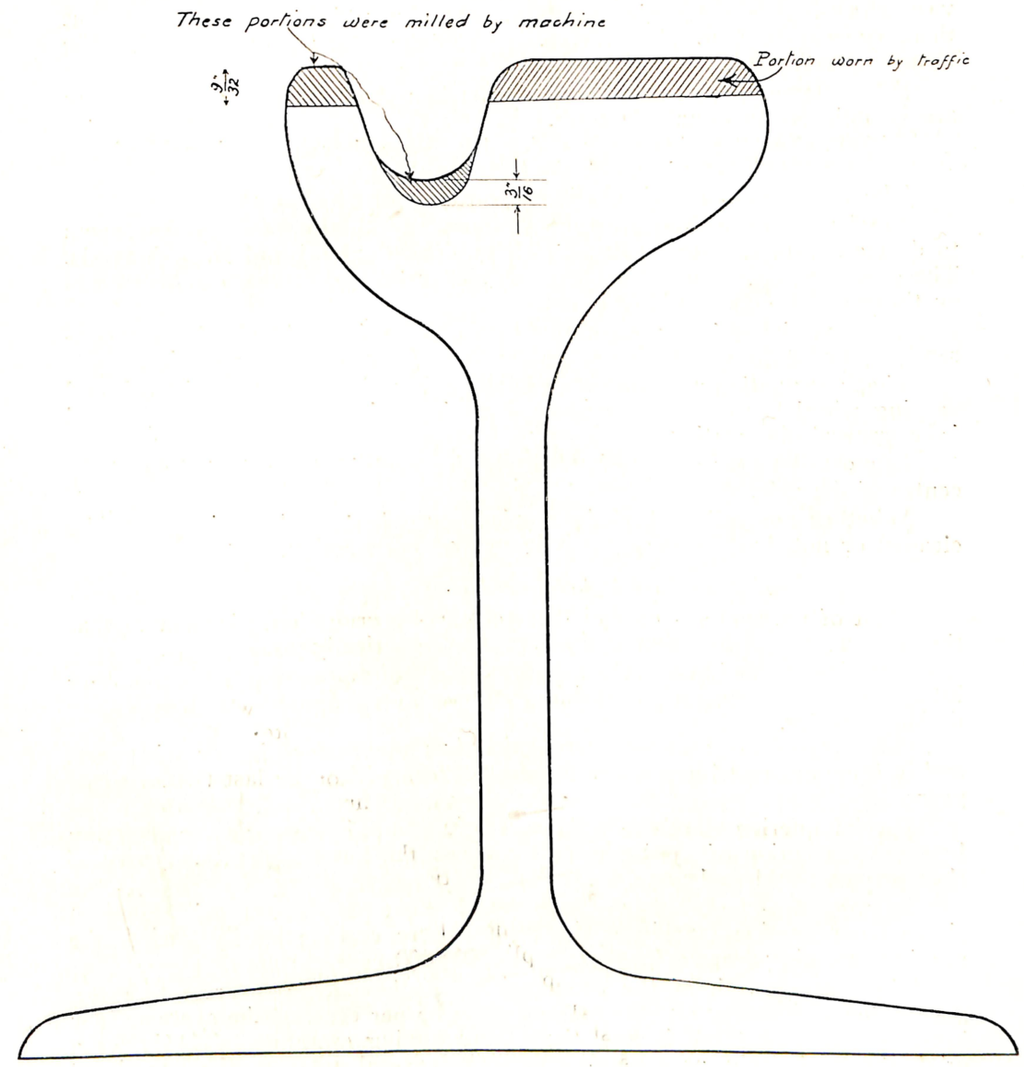
It is worthy of note that corrugation is produced both by steel tyres and chilled wheels, and by tyres which differ widely in hardness and composition.

The vast majority of systems use a coned tread, and the four which use a flat tread are not free from corrugation. It would, therefore, appear that the form of the wheel tread plays only a subordinate part in producing corrugation.

In view of the suggestion that torsion of the axles is an important agent in producing corrugation, it may be noted that the three largest diameters of axles are in use on systems which are badly corrugated.

It is rather remarkable, in considering the relation of wheel gauge to rail gauge, to find that 11 systems put their wheels on to the same gauge as the

87 LB RAIL



rails, and, of these, 8 systems have little or no corrugation. The great majority of systems allow a clearance of about ⅛in.

NOTE.—Information supplied by Mr. Mattinson, from Replies to Queries *re* Permanent Way, submitted at Glasgow Conference, 1911, showed that four of the eleven systems now state that they allow a clearance between the wheel gauge and the rails.

The great majority of the replies state that there is no variation in the diameter of the wheels when new. All admit that there is a variation in service, which is an average of about ⅛in. The bulk of the systems admit that there is from ⅛in. to ¼in. variation when the wheels are removed to be turned or scrapped.

All systems, except one, claim that, when the wheels are turned, they are brought to an equal diameter.

NOTE.—The Committee are satisfied that, in actual practice, uniformity of diameter is not obtained.

The weight on each wheel varies from 2¾ tons to 3 tons.

Breakages of the axles are very common, and, in almost every case, seem to develop from minute cracks, which gradually extend and work inwards. These seem to take place impartially on systems which have corrugation and on those which claim to have none.

The material and manner of application of the brake blocks do not apparently enter into the question, so far as can be judged from the replies.

That corrugation appears on systems having different types of truck and varying wheel bases is very evident, both from the Replies to Queries and from general observation.

In most cases the centre of gravity of the truck is about the height of the centre of the axle.

Whether one rail or both be sanded, or whether the rail groove be cleaned or not, has no apparent influence on corrugation.

GENERAL.

Most of the systems replied that they had corrugation, nine stated that they had none, and four stated that they had practically none.

The Committee have not yet been able to find any system which is absolutely free from corrugation marking, although on some systems it is a negligible quantity.

On some of the systems corrugation has shown for nine or ten years, and in others of equal age it has developed only within the last two or three years.

Special queries were made to ascertain if there were any connection between the action of the brake and corrugation, but the great majority of the systems could find none.

In regard to the number of cars which must pass over a rail before it showed corrugation markings, the replies were extraordinarily varied, the numbers ranging from a few cars up to 900,000 cars.

The wave length of the corrugation, or distance from crest to crest, approaches uniformity on all systems. On 85 per cent. of the systems it is between two and three inches, the others having extremes of 1½in. as a minimum, and 7½in. as a maximum. On several systems, the occasional longer wave length seems to be a multiple of the usual wave length.

The replies were almost unanimous that corrugation was quite frequent where coasting was habitual.

Most of the systems were unable to find a conclusive relation between corrugation and speed of the cars, and this was further confirmed by special queries sent out at a later date. There was a general impression that corrugation was more pronounced at speeds over ten miles an hour.

There were nine replies that corrugations could be removed by the cars themselves, and, in two cases, it was stated that this took place after the rails had been lifted and repacked.

This matter is fully dealt with later in the Report, under "Occurrence and Characteristics of Corrugation." See next page.

It was largely the experience that corrugation was very common on single line, where the cars travel in both directions, and seven systems stated that it was worse under these conditions.

Very few systems find indications of corrugation on the wheel tyres; six replied that they had such indications, but the information on this point does not appear to be conclusive.

Where corrugation exists, it is found both on straight track and on curves.

It is very significant of the complexity of the subject of corrugation to consider the replies to the query, "Have you arrived at any conclusion as to the cause or causes of corrugation on your lines?" The great majority made no reply. In seven or eight instances, "I have no theory" was the reply made by those who, a few years ago, strenuously advanced or supported one theory or another.

Occurrence and Characteristics of Corrugation.

A great mass of evidence was collected and carefully sifted, and the following observations in regard to the occurrence and markings of corrugation were arrived at:—

1. Corrugation occurs very widely on systems with electrically self-propelled rolling-stock, the construction of which necessitates a low centre of gravity; also on cable systems, and, to a relatively small extent, on steam railways.

   Based on the Replies to Queries. Occurrence of corrugation on cable tracks at Handsworth, Streatham, and Douglas. Occurrence of corrugation on many steam railways, amongst others being the Midland, the North-Eastern, the Glasgow and South-Western, the North London, etc.

2. The distinguishing characteristics are the occurrence on the head of the rail of small crests and hollows, at approximately equi-distant intervals, the crests being generally brightly polished, and frequently inclined at an angle to the longitudinal axis of the rail.

   Based on analysis of a large number of records and observations, and the replies to special inquiry sent to a number of tramway systems.

3. On tramway systems, the corrugation on the rails shows, in almost all cases, a wave length or distance from crest to crest which is between 2in. and 3in.

   Based on the replies to query No. 6 and many independent observations.

4. Corrugation on the rail tread is sometimes accompanied by vertical corrugation or markings on the check or guard, but in many cases this is not apparent.

   Based on the replies to query No. 3 and a number of special observations on rails.

5. On almost every system, it occurs abundantly at places where the brake is very seldom applied, and is not any more frequent nor pronounced at places where the brakes are regularly applied, as at stopping places, It may be concluded, that the great bulk of corrugation is not due to any action of the brake.

   Based on replies to queries No. 2 and independent observation.

6. Corrugation is very common on single track, where cars run in both directions, and on some systems the worst examples are on single line under such conditions.

   Based on replies to query No. 11 and personal observation by members of Committee.

7. On track where the cars run in one direction only, the corrugation marking is frequently inclined from the gauge edge backward from such direction, whilst on track where the cars run in both directions it is generally at right angles.

   Based on replies to special inquiry sent to a number of systems and special observations.

8. Corrugation is produced both by single track cars and bogie cars.

   Based on replies to rolling-stock query No. 23 and general query No. 21.

9. Corrugation is frequently produced on tramway permanent way material manufactured by processes other than rolling, such as cast-steel points, manganese rails, etc.

   Based on replies to general query No. 22 and personal observations by Committee.

Mr. Mattinson obtained photograph showing corrugations continuing through the rolled rail, over cast-steel points, through the manganese insert of same, and on to the adjoining rail beyond, also on the opposite side over a forged steel tongue. (See Illustration.)

Mr. Holt submitted series of photographs, showing corrugation on sharp curves on cast manganese steel rails, also on crucible cast-steel point.

EXPERIENCE ON STEAM AND HORSE TRAMWAYS.

Reports received from officials who had operated steam tramways at Burnley, Leeds, and Bradford for many years stated that corrugation was unknown on such systems.

It was also reported by those who had been in charge that, on horse-drawn tramways, there had been no signs of corrugation.

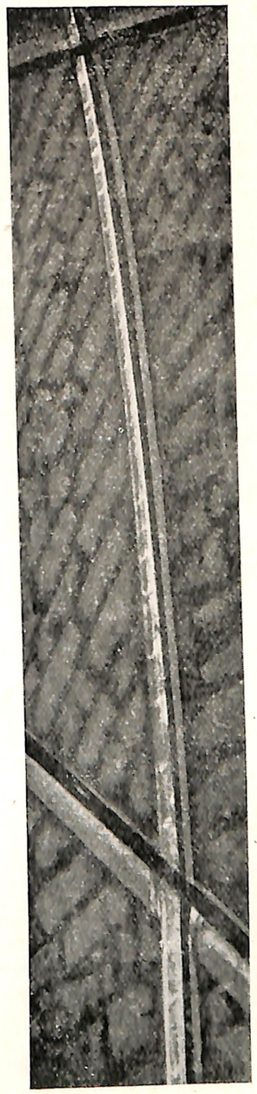
OCCURRENCE ON A CABLE TRAMWAY.

The Committee visited the corrugated portions on the Birmingham-Handsworth Cable Tramways, and noted that the corrugation was very apparent, and the result could be plainly heard on the passage of the car. They also noted that the wave length was generally short, about 1¼in. from crest to crest.

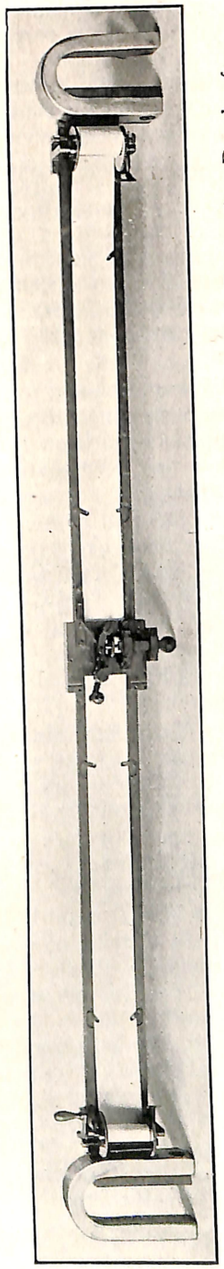
The diameter of the car wheels was about 24in.



Example of Corrugation on Crucible Cast Steel Point.
Taken from "Interim Report on Rail Corrugation."



Example of Corrugation on 30′ 0″ Radius Curve, Manganese Steel Rail, Record taken February, 1911.



The Woods-Gilbert Rail Planer Company's Recording Instrument for Recording and Registering Depth of Corrugations, Dished Joints, etc., on Tramway and Railway Rail Treads.

The Committee were informed that the cars on that portion of the tramway inside the city were formerly run at a speed of seven miles per hour, and no corrugation appeared, whilst, on the portion of the system outside the city, the cars were run at a speed of nine miles per hour, and extensive corrugation developed. The speed of the cars running on the inside section was subsequently increased to nine miles per hour, and then corrugation became general on that section, showing that the critical speed on this system was between seven and nine miles per hour.

ALTERNATE PRODUCTION AND REMOVAL OF CORRUGATION.

A very interesting and instructive example of the production and removal of corrugation and its reappearance took place on the Bexley Heath Tramways. A portion of the tramway on the Northumberland Heath section was leased to the Erith Council. Up to this time there had been no corrugation on these lines. On completion of the agreement in 1908, the Erith Council cars began to run on this length, the Bexley cars being withdrawn.

Within a few weeks, Mr. Mittelhausen, the Manager, observed corrugations forming, and in four months these were quite pronounced. The corrugations were especially apparent on the two hills leading to Courtleet bottom, and appeared both on the curves and on the straight. At one place the corrugation was very distinct on both rails. Most of the places referred to are single line.

At the end of twelve months the agreement terminated. The Erith cars then ceased to run, and the service on this portion was resumed by the Bexley cars. From this date, the corrugation began to lessen and disappear, and in fourteen weeks it had practically gone.

After an interval of twelve months (July, 1910), the Erith cars alone again began running, and corrugation was apparent in eight weeks. The Erith cars have run continuously since July, 1910, and the lines are at present corrugated.

The Erith cars and the Bexley cars are very similar in construction and weight, but the Bexley cars ride more easily owing to improvements in the springs. One noticeable difference is steel tyres on the Erith cars, and chilled wheels on the Bexley cars.

The speed of the two sets of cars is very similar, and the braking arrangements are the same, except that the Erith cars have Newall magnetic track brakes, and the Bexley cars have no track brakes. The diameter of the wheels is the same on both sets of cars.

On the Altrincham route, at Manchester, between Stretford and Sale, for a distance of a quarter of a mile, the track, which is level, and over which a speed of 16 miles per hour is in operation, was very badly corrugated, as per records submitted to the Committee. There being no property abutting on this track, it was agreed to leave the corrugations to see what developments would take place. Up to the time when the corrugation attained its maximum developments some 281,000 cars had travelled over the lines during a period of seven years; the disappearance took place during a period of about twelve months, with 86,000 further cars over the lines, and they recommenced to appear after the passage of some 86,000 more cars, and in a further period of about twelve months.

CORRUGATION MARKINGS ON MUDDY DEPOSIT ON RAILS.

Characteristic corrugation markings have been observed on the greasy muddy deposit found on the rails under certain climatic conditions in some large towns. Usually, this is produced by one car, and is removed by succeeding cars.

The Committee considered in detail, and classified, a large number of drawings and photographs of corrugation from different tramway systems, and endeavoured to connect the distinctive features of the corrugation markings with the different conditions of location, car service, speed, etc., under which they were produced.

The detailed analysis did not indicate any definite relation between the shape, pitch, and appearance of the corrugation markings, and the speed, gradients, curvature, traffic, or the use of power, at the respective places.

The following general observations were, however, made:—

There were indications of corrugation in every possible position—viz., on up and down gradients, on straight and curved track, on one or on both rails, or on either rail separately, alternately, and also intermittently.

Periodical records of corrugations at the same places did not indicate any tendency of the ridges to creep along the rail, although the markings appeared to vary in intensity, and to merge from the defined ridge type to the patch type, and vice versa. (See Figures 7 and 8.)

The patch type of corrugation appeared to exist in conjunction with speeds over twelve miles per hour.

The Committee consider it worthy of note that high parts of corrugation, which, being brightly polished, would suggest the greatest wear, should retain such position, while the lower parts, being often dull, and not appearing to receive so much wear, remained hollow.

It would naturally be assumed that this could only be the case if the crests had become hardened, and, therefore, more wear-resisting.

STRUCTURE OF CORRUGATED RAILS.

Sections of rails removed from the tracks at Glasgow, Leeds, Manchester, and Sheffield, and subjected to the action of an acid bath, showed the following characteristics:—

It was clearly evident that the acid attacked the hollows considerably more than the crests, establishing the fact that the metal at the crests was considerably less affected by the acid, and was more dense than the metal in the hollows.

The metal was not affected by the corrugating influence at a depth of 1-16in. below the surface, showing that the corrugation effect is practically superficial.

The etching of rails not having corrugation showed a structure very similar to that in the hollows of corrugation.

Corrugation is essentially a periodic recurrence of crests and hollows on the head of the rail.

In view of the recent considerable addition to the knowledge of the state of the rail, it might be of value to endeavour to deduce the action which causes these hollows.

There appear to be only three actions possible:—

(a) By the material being repeatedly subjected to a hammering or pressing-down action, resulting in a hollow at that place.

(b) By cold-flowing of the material, so that it travels away and is piled at the crests or extruded into the groove.

(c) By a number of intermittent grinding actions taking place only at the places which become hollows, so that the material at these places is removed by attrition.

If the action (a) took place, the structure of the material in the hollow would surely be more dense and harder than where the action did not take place—i.e., at the crest. All the evidence shows that the reverse is the case. The material in the hollow is less hard and more open than at the crests. It seems improbable that either (a) or (b) alone causes the hollows. It is, however, clear that cold-flowing does take place, and, if this were combined with a certain amount of attrition, the result would probably be in accordance with the actual state of the rail structure, as demonstrated by the various tests made.*

It seems, therefore, not unlikely that, at certain periodic intervals, cold-flowing and attrition take place, resulting in hollows.

The Committee consider that the production of corrugation by the cold flowing of the material, due wholly to rolling load, without slip or skid, is very unlikely.

The information collected by the Committee (by experiments and otherwise) amply showed that slip and skid are continually taking place, and that a pure rolling motion very seldom takes place, even for one complete revolution of the wheel.

The Committee have acquired strong evidence that the result of this continual slip and skid is attrition and cold-flowing of the material of the rail. This is coupled with the transverse flow previously referred to.

The general information placed before the Committee, coupled with the striated appearance of the corrugated rails, would suggest that corrugation might be created by the alternating slip or skid and rolling action of the wheel during its passage along the rail. Slipping or skidding, possibly in conjunction with rotaton, would appear to take place in the hollows and pure roll, coupled with increased pressure at the crests.

A number of experimenters and theorists have advanced the theory that cold-rolling is alone the cause of corrugation. The action is said to take place when the pressure due to the wheel exceeds the elastic limit of the steel. There is supposed to be a cumulative transference of the material ahead of the wheel until the latter runs over the crest. A short experience of tramway operation, and the actual production of corrugation, is sufficient to show that this theory leaves much to be explained. The following are some established facts which do not fall in with this theory:—

That Bradford, with the softest rails by composition, and the hardest tyres, has comparatively little corrugation.

---

* Mr. W. Worby-Beaumont was unable to subscribe to the conclusions of the Committee relating to the method of production of the hollows of the corrugation, or as to the effect of slipping and attrition, and he objected to the expression "cumulative transference of the material," and to the conclusion that if corrugation were due to the rolling of the wheels on the rails, the material in the hollows should be harder than that upon the crests. He appeals to the rolling by the loaded wheels and compression of the surface material, as alone the originating cause of corrugation.

Almost every system had no corrugation for a number of years, while these same systems now have corrugation beginning on rails very soon after laying? Wheel diameters and weights have not altered.

Cuts were made across head of rail on London County Council Tramways, and yet no effect was produced on corrugation. There could be no transference of material across the cuts or trenches, and, according to the theory, there should have been no corrugation.

Similarly the Leeds' photos. show a corrugation crest just at *and beyond* a joint across which the material could not pass.

Corrugation markings have been produced in paint, sand, snow, etc., where there can be no accumulation or deformation to form a crest.

Corrugation occurs on cable lines where the cars are relatively light; also it has been produced by an increase in speed only on such lines.

On tracks with considerable cross-fall, corrugation should always appear on the low rail of the straight, to be in accordance with this theory, but in actual experience this is not found.

Findings in Regard to Corrugation.

As the result of their investigations, the Committee have arrived at the following interim findings:—

Corrugation occurs very widely on systems with electrically self-propelled rolling-stock, the construction of which necessitates a relatively low centre of gravity; also on cable systems, and, to a relatively small extent, on steam railways.

The check or guard is not a necessary factor in the production of corrugation.

On almost every system, it occurs abundantly at places where the brake is very seldom applied, and is not any more frequent or pronounced at places where the brakes are regularly applied, as at stopping places. It may be concluded that the great bulk of corrugation is not due to any action of the brake.

The occurrence of corrugation is not dependent on the number of cars which have passed over the rails.

It is not necessary that the track, or the rolling-stock, or the wheel profiles should be in a worn or defective condition in order to produce corrugation. With all these factors in excellent condition, a car travelling with power under ordinary conditions will readily produce corrugation.

Corrugation appears on the rails independently of whether the wheels are being actively driven by the motors or not. The Committee are of opinion that the explanation of this may be the slip and skid taking place owing to the different diameters of the wheels, which difference largely results from the unequal wear produced by the relative difference in speed of the two motors.

Corrugation produced by one set of cars may be entirely removed by another set of cars running in place of the first. It may also be caused and removed by the same set of cars under apparently the same conditions.

The pitch of corrugation is independent of the speed of the cars producing the same.

Corrugation does not exist on tramway rails as received from the rolling mills.

Corrugation has been produced by every known type of electric car, and the pitch and characteristics are independent of the type of such car producing the corrugation.

It is suggested that the brightness of the crests of corrugation, as compared with the comparative dulness of the hollows, is due to a purely rolling action under increased pressure over the crests, and that other portions of the rail are not subjected to a purely rolling motion, but to the action referred to on page 14. Hence their dull appearance.

Extract From "THE TRAMWAY AND RAILAWAY WORLD," Of February 10, 1916.

RAIL CORRUGATION.

A solution of this question has not yet been found. Naturally it is not easy to find a remedy for an evil so long as the cause or causes of the evil are unknown. The two British tramway associations, which, a few years ago, were hard at work investigating the problem, appear to have slackened their efforts; at all events, little in the way of reports from the investigation committees has recently been published. The subject is again being discussed in the American engineering Press, but it cannot be said that any great new light has been thrown on it. One writer thinks that the trouble is caused by load concentration due to reduced area of contact, as the result of irregularities, or of a difference between the contours of the rail head and the wheel tread. This theory has the advantage that its accuracy can be tested by providing wheels and rails that conform to one another. The writer in question has tested his theory, with the result that no corrugation appeared in five years. Mr. R. B. Holt, in his work on tramway track, points out that much wear of rails is caused by the wheel tread and the rail head being of different contours. A new tyre will not fit a worn rail, and vice versa, and the remedy is to design the rail head so as to fit a partially-worn tyre. This remedy for irregular wear is the same practically as the American's remedy for corrugation, but if it were always effective there should be less corrugation than we see. A fairly-worn tyre and a fairly-worn rail represent ordinary conditions, and they are generally associated with a full bearing across the width of the rail tread. Another American writer revives the old idea that corrugation is caused by rigid track construction. But there are plenty of lines in foreign countries, some of them steam railways, which are laid on sleepers so as to give an elastic track, and yet corrugations appear. Years ago reports from India showed that railway rails were corrugated when one kind of ballast was used, and not corrugated when another kind was employed. It is to be feared that the Americans are no nearer the solution of the problem than we are.

Extracts from Mr. R. Bickerstaffe Holt's work, entitled "TRAMWAY TRACK CONSTRUCTION AND MAINTENANCE."

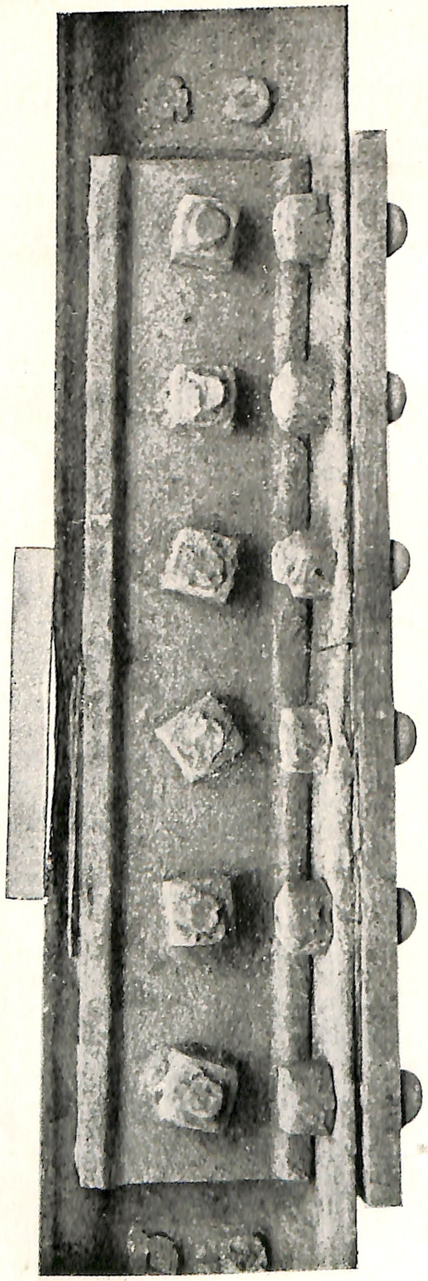
Published in 1915 by the "Tramway and Railway World," London.

RAIL JOINTS.

"In up-to-date tracks the well-anchored and supported rails permit the wheels to travel to the extreme end of the rail without deflection, the trouble being caused by the slight drop of the wheel as it bridges the gap between the "running" rail and the "running-on" rail. This drop is very slight to commence with, but it increases, and causes a decided depression on the end of the "running-on" rail, which is, of course, equal to the widening of the gap between the two rail ends. The wheels roll off the end of the "running" rail, and alight some distance from the end of the next rail, the distance varying in this country from 1in. to about 6in., according to the speed of the car. Block shows a typical "dished" or "hammered" mechanical joint. It will be noticed that the "running" rail has scarcely received injury, whilst the "running-on" rail has been battered hollow, and has apparently been raised, judging from the presence of the liners between the rail head and the fish plate."
See illustration, page 26.

RAIL WEAR

"The pertinent question, "What is the life of your rails?" is one of the most difficult of track problems, and it is not possible to answer it with any degree of accuracy on account of the numerous factors entering into the cause of rail wear, which appear to vary on each particular system. The wear of tramway rails depends chiefly upon the operating speed, the weight and design of the cars, the traffic density, the number and position of the stopping places, the frequent use of the brakes, the grades and curvature of the route, the vehicular traffic, the design of the rails and wheel tyres, the upkeep of the same, and, finally, upon the manufacture and composition of the rails. On account of the exigencies of the service and the local conditions, the design of the rails, their composition and manufacture, and the upkeep of the tyres are probably the only factors in rail wear that can be controlled. It is essential, therefore, that every consideration should be given to these questions, upon which depends such an important phase of tramway economics. It is not possible to compare the rate of wear on different tramway systems, or even on different routes on the same system, unless the general conditions are first of all proved to be identical. A few examples will serve to illustrate the truth of this statement. Taking the case of the operating speed, it may be conclusively proved that rails last longer on routes where there is a slow, frequent service, than where there is a less frequent service of cars run at



Badly-battered Mechanical Joint, as shown by the Straight Edge.

From R. Bickerstaffe Holt's Book on Tramway Track Construction.

higher speeds. An instance of this kind on the Leeds tramways showed that, while forty million tons of car traffic were carried on a straight, level track, where the speed did not exceed 8 miles per hour, not more than one-third of this weight was borne by the rails on a similar route, where the speed was about fifteen miles per hour."

RAIL GRINDING.

"On the majority of British tramways it is necessary that such machinery should be regularly employed on the removal of corrugations; otherwise much damage is done to both the rails and the rolling-stock if the corrugations are permitted to become too pronounced. It is true that the effective life of the rail is decreased, to some extent, by this treatment, but, on the other hand, **if corrugations are left untended they generally reach a stage where battering commences, and from this point the deterioration is rapid, and remedial measures are impossible."**

Extract from
"ELECTRIC RAILWAY JOURNAL" OF U.S.A.
Of April 1, 1916.

VIBRATION THEORY OF RAIL CORRUGATION.

In the issue of last week we published an abstract of the somewhat radical ideas on rail corrugation recently put forward by A. Meyer, of the Greater Berlin Street Railways. His theory, to the effect that corrugation is due primarily to high-frequency vibrations in the rail (which thus acts like a banjo string) has logical grounds, at least, because the extraordinary regularity of most corrugations gives evidence that vibration must exist somewhere. Mr. Meyer does not deny the existence of contributory causes for the phenomenon, being in accord, as a matter of fact, with R. C. Cram in his belief that the shape of the rail head has an appreciable influence. However, his suggestions for obviating the difficulty are aimed solely toward the elimination of such rail vibrations as may produce waves of sufficient amplitude and frequency to cause displacement of metal in the rail head wherever the wheel strikes the crest of one of them. This answer to the baffling problem of corrugation will, no doubt, be of interest to way engineers, and the proposed remedy of having so flexible a track construction that the vibration period becomes too long to cause severe impacts is well supported by practical experience. On the other hand, the theory, taken in its entirety, is not without weak points. Carried to its logical conclusion, it would mean that the worst condition which could prevail would be a rigid track (to produce the greatest severity of vibration) and hard wheel treads (to produce the greatest displacement of rail metal). Such a condition might be considered to be presented by the concrete track supports and chilled-iron wheels that were common some years ago, yet at that time corrugation was apparently less of a problem than it is in the present day, when relatively soft steel wheels and flexible track are more common. As the first book devoted entirely to the exposition of one theory of rail corrugation, the publication is interesting. We do not believe, however, that it will accomplish very much in settling the controversy. What is needed is less theory and more actual proof.

Extracts from

"THE ELECTRIC RAILWAY AND TRAMWAY JOURNAL"

OF LONDON, March 10, 1916.

THE CAUSES OF CORRUGATION.

We make the following excerpts from some very interesting correspondence on this subject which has been published in our New York contemporary, the "Electric Railway Journal," and referring to previous articles therein. Mr. T. F. Mullaney, chief engineer, Third Avenue Railway, New York, says, inter alia:—

"From my own observations I am of the opinion that rail corrugations are the result of a combination of things, such as rapid acceleration, high speed, severe braking, in conjunction with the use of steel wheels.

"Corrugations on surface roads were practically unknown ten or twelve years ago. At least, there was very little trouble that could be ascribed to them. About this period rolled-steel wheels or steel-tyred wheels were generally introduced on surface roads. Since then they have been used very extensively. By their use flat wheels, which were so common with the chilled cast wheel, have been largely eliminated, but it seems to me that we have transferred the flats from the wheels to the rails. My reason for forming this opinion is that, up to 1908, there were no noticeable rail corrugations on the Third Avenue system on Manhattan Island. It was about this time that steel wheels were introduced, and shortly thereafter corrugations began to appear and developed very rapidly, becoming so serious and noisy that we received numerous complaints, and found it necessary to file or grind them out. On 125th Street the rails became so badly corrugated that, on the advice of steel experts, and as the only means of preventing corrugations, we installed a new and heavier rail, weighing 125lb per yard. But after this rail had been in service a few weeks it became as badly corrugated as the old. This rail is carried on a 6in. by 6in. longitudinal wooden stringer for its entire length. After the cars on our Manhattan lines had been equipped throughout with steel wheels, the cars on our Bronx lines were similarly equipped. Corrugations appeared almost immediately, although up to that time the Bronx lines had been in operation about fifteen years without developing corrugations. Therefore, it seems to me that, if cars of approximately the same weight and speed are operated with chilled cast wheels for fifteen years without noticeable corrugations, and corrugations appear when steel wheels are substituted for the cast wheels, the trouble is not in the rails, but in the wheels. I am also of the opinion that double-truck cars, with cast pony wheels and steel driving wheels, make corrugations faster than any other type, as practically all of the braking is done on the driving wheels. Furthermore, corrugations may be encouraged by the nosing due to short wheelbase. It is held, too, by some engineers that corrugation is due, at least in part, to the chattering of rolls at the mills. In other words, the new rail has incipient corrugations. Whether this is true or not, the chattering of the tools used to turn a steel wheel certainly does form on the tread very perceptible incipient corrugations. Therefore, if the steel wheel is ground after turning, at least one possible cause of corrugation would be removed. Concerning the suggestion in the letter in your issue of January 8th, that modern track construction is responsible for corrugations, I would point out that some of our worst examples of corrugations are on tracks of the older type of construction which have been in service twelve to fourteen years. I have particularly in mind one stretch of corrugated track twelve years old, consisting of 107lb. rails, laid on wood ties, on dirt foundation, in granite pavement. This shows how impartially corrugations appear on the older as well as on the later types of track construction."

From a long letter on "High-Carbon Steel and Rail Corrugation," written by Mr. W. B. Potter, engineer, railway and traction department, the Connecticut Co., New Haven, we take the following passages:—

"It seems to me that Mr. Cram's paper shows that we are not gaining by the use of more costly steel, but are increasing the costs of both construction and maintenance.

"We have recently made an inspection of corrugated rail on this company's lines, and find that it is confined mostly to rails 7in. to 9in. in height, in most cases of open-hearth steel, with fairly high carbon content. It would appear that we are following a false lead in our efforts to cut down maintenance costs by using these higher-priced steels, which are perhaps not as fully suited to our needs. This would appear to be true if corrugations are now 'accepted with complacency'; if now we are wearing out our rails with 'expensive and wasteful grinding'; if now we are losing '0.001in. per month,' or 0·412in. of head per year.

"The following proposition is undoubtedly true:—If the extra cost of special steel, plus the extra cost of equipment for grinding, plus the labour cost of reducing corrugations in the special steel rail for a term of years representing the life of the old standard rail, is less than the cost of renewing the old standard rail at the end of that life, the new special steel is a paying proposition.

"I doubt, however, that it is a paying proposition, for with noted and assumed wear, as above, for new and old composition steel rails, improved steel rails, under the most favourable conditions, would wear but twice as long as the older standard."

Mr. A. E. Harvey, chief engineer, Metropolitan Street Railway Co., Kansas City, says:—"There is no theory as to the cause of these that will fit absolutely in each case. The corrugation occurs in sections of rail rolled many years ago, and in the rails rolled in recent years. It also existed before steel wheels were in use on any of our cars, and it has occurred since practically all of these wheels have been removed. We have instances of the latter on practically new track laid on rigid foundations. Some of our worst cases of corrugation occur upon loose rail or on resilient foundations. Various theories have been advanced in attempts to determine the causes of corrugation, but none will stand the test of absolutely all conditions."