INSTITUTE OF ENGINEERS, AUST.

Prolonging the Life of the Tramway Rail.

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Summary.

This paper describes various factors contributing to the life of the tramway rail, and outlines some of the methods adopted in Adelaide with the object of prolonging rail life generally. The subjects discussed include the following :—The design and chemical composition of rails, causes of rail wear, corrugation and corrosion of rails, the "in situ" process of hardening the surface of rails, the electric welding process of "building up" the head and check of rails around curves, and the manufacture of junction special work with steel rails.

The author also submits a design for a grooved tramway rail—104 lb. per yd.—and suggests this design as being suitable for use on tangent track, or as an "outer" or "high" rail on curved track.

Introduction.

During recent years the operation of heavier and more powerful rolling stock, at faster speeds on tramways, has created conditions of rapid rail wear, and many efforts have been made by engineers in conjunction with rail manufacturers to improve the quality of the rail steel. The introduction of high carbon, medium manganese, and alloy steel rails, the "sorbitic" hardening and "oven" regulated cooling of rails during manufacture, are some of the results obtained to date, but much work has yet to be done to obtain a steel with increased resistance to abrasion, without sacrificing resistance to fracture, and at a reasonable cost.

Improving the quality of the rail steel is, however, only one of the many factors contributing to the problem of prolonging rail life. The work of track construction and maintenance affords the engineer many opportunities of effecting improvements and devising methods of counteracting abnormal wear, and it is only by the careful observation of track movements and systematic procedure that the best results are achieved.

There is a vast difference in railway and tramway operation. Tramway cars, on which all wheels are either driving or braking, are operated on a more frequent headway, over sharper curves and steeper grades, and although the maximum speed may not be as great as on railways, the speed is boosted up by rapid acceleration and sudden braking, owing to the numerous stopping places and to meet the exigencies of other traffic. With the low centre of gravity of motor bogies and the greater unsprung loads of tramcars, conditions of rapid wear are thus provided, necessitating heavy expenditure on the maintenance and renewal of tracks.

The Effective Life of the Rail.

Owing to the numerous factors contributing to rail wear, which appear to vary, not only on different tramway systems but on tracks in the same system, it is very difficult to predetermine with any degree of accuracy the effective life of the rails. The main objective is, however, to secure the maximum of service for the full depth of allowable wear. In Adelaide, with the majority of rails in service, this depth is 9/16 in. before the wheel flange is riding on the bottom of the rail groove, when the rail is considered to be worn out. (See Fig. 1.) It is not always possible to secure this full depth of wear, e.g., when renewing sleepers or foundations it would be uneconomical to leave rails in the track with less than 3/16 in. of remaining wear, as this would necessitate opening the roadway again in a comparatively short time. In this case, good second-hand rails are put in, which will outlast the rails left in the track.

It is obvious that the life of the rail cannot be gauged by time alone, as rails over which there is an infrequent service may last from 40 to 50 years and yet may not have carried the number of cars or tons of traffic that rails on a track lasting from 10 to 15 years have carried.

After rails have been in service for a few years it is possible to estimate fairly accurately their remaining life, based on previous wear for a known number of car passes. Diagrams of the rails are taken at frequent intervals, the depth of wear measured and averaged, and the number of car passes and the period of service ascertained. The problem is then a simple one of proportion, but has proved fairly accurate in practice.

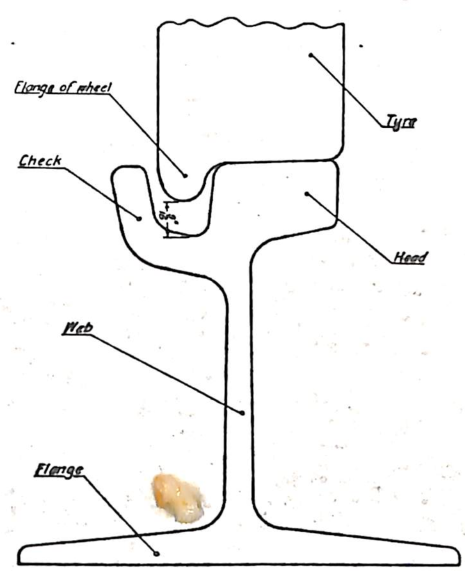

Fig. 1.—B.S.S. No. 2 95lb. Rail.

Causes of Rail Wear.

The wear of rails is exceedingly variable and comparisons are not easily made with different undertakings, on account of variations in rolling stock design and topographical conditions. Among the factors contributing to rail wear are the following.—

- Chemical composition of rail steel.
- Speed, weight, and frequency of cars.
- Acceleration and deceleration.
- Wheel-rail contact.
- Rail corrugation.
- Rail corrosion.
- Irregularities of track.
- Debris on rails.

Chemical Composition.—The first steel rails used in England were manufactured by the acid Bessemer process, followed by the acid open hearth, and under the conditions existing at the time, gave excellent results. Later they were produced by the basic Bessemer and basic open hearth processes, but the majority are now made in basic open hearth furnaces.

The outstanding characteristics of early rails were :—a rather low carbon content, about 0.4 per cent., manganese up to 1 per cent., and sulphur and phosphorus in excess of present-day specifications.

Owing to the comparatively small mills in use, the rolling operation was much slower, so that the finishing temperature was far lower than with the modern mill. With steel of the same composition this would tend to produce a harder rail.

Another factor which may have had some bearing on the good quality of early rails is that when first laid they were subjected to comparatively light axle loads, which might induce a gradual work-hardening on the rail head, resulting in a harder wearing surface.

During the original construction of the Goodwood and Magill tracks, rails of 0.38 and 0.52 per cent. carbon were used alternately in places, and the positions of each recorded.

Diagrams of the rails were taken after 12 years in service (Goodwood 335,194 car passes, and Magill 359,720 car passes) rail has work-hardened, as in both cases the rails have carried the same loads under similar conditions.

Between the years 1908 and 1935, various sections of rails and classes of steel have been used in Adelaide. The B.S.S. No. 2 (95 lb.) and B.S.S. No. 2c (101 lb.) rails were standard practice on tangent and curved track, respectively, except through park lands, etc., when 60 lb. and 80 lb. Tee-head rails were used. Later, the B.S.S. No. 6 and B.S.S. No. 6c (96.4 lb. and 103.2 lb.) were adopted, and in 1927 the 102.06 lb. rail was introduced for tangent track and as the outer rail on curves.

TABLE I.

CHEMICAL COMPOSITION OF STEEL RAILS (M.T.T. ADELAIDE, 1908-1935.)

Year of purchase.	Type of rail.	Chemical Analysis.				
		C. %	Si. %	Mn. %	S. %	P. %
1908	B.S.S. No. 2 95 lb.	0.38		0.84	0.06	0.06
"	" " Silicon	0.52	0.25	0.83	0.06	0.06
"	" " 2c 101 lb.	0.51	0.21	0.80	0.06	0.06
1923	" " 6 96.4 lb.	0.63	0.21	0.80	0.04	0.03
"	" " S/Sorbitic	0.60	0.21	0.78	0.03	0.03
1927	A/M 102.06 lb.	0.62	0.12	0.78	0.03	0.03
"	" 102.06 lb. Silicon	0.60	0.22	0.80	0.03	0.03
"	" " " Sorb.	0.60	0.22	0.80	0.03	0.03
1932	B.S.S. No. 6c 103.2 lb.	0.64	0.23	0.78	0.02	0.04
"	" " Sorbitic	0.64	0.23	0.78	0.02	0.04
1935	A/M 102.06 lb.	0.60	0.13	0.79	0.03	0.04
"	" " Sorbitic	0.60	0.13	0.79	0.03	0.04
	B.S. Specification No. 2, 1927.	0.60 to 0.70	Max. 0.30	Max. 1.00	Max. 0.06	Max. 0.06

It will be observed that there has been an increase in the carbon content and a decrease in the sulphur and phosphorus, while maganese has remained fairly constant. The majority of rails used in Adelaide since 1927 were sorbitically treated during manufacture, the most recent being "regulated sorbitic oven cooled" rails.

In 1930, sections of track along Grenfell Street, City, and Payneham Road, St. Peters, were renewed, using Sandberg high silicon and Sandberg high silicon sorbitic rails, and the positions of each were recorded. Diagrams of the rails taken after 12 years of service reveal less wear on the sorbitic rails:

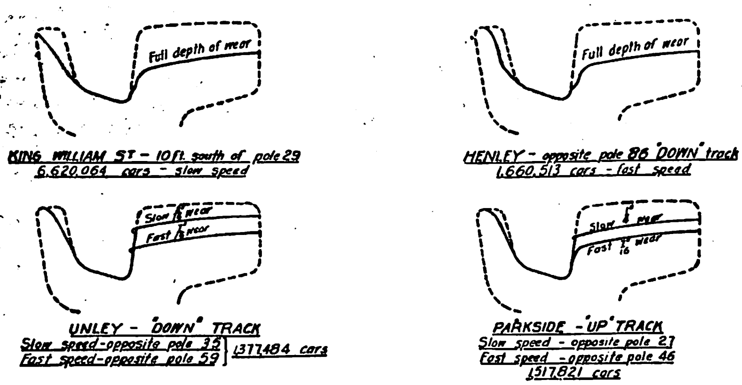

Fig. 2.—Effect of Operating Speed of Trams on Rails—B.S.S. No. 2.

Speed, Weight, and Frequency of Cars.—In the case of the operating speed, it may be proved conclusively that rails show less wear on tracks over which there is a slow but frequent service than on those where there is a less frequent service at higher speed.

The diagrams, Fig. 2, show full depth of wear (9/16 in.) along King William Street, City, after 6,620,064 car passes at a speed of, approximately, ten m.p.h., and similar wear on Henley route after only 1,660,513 car passes at a speed of, approximately, 25 m.p.h. The wear of rails on fast and slow speed sections of Unley and Parkside routes are also shown in Fig. 2.

TABLE II.

CAR PASSES PER $\frac{1}{16}$ IN. DEPTH OF RAIL WEAR—SLOW, MEDIUM, AND FAST SPEEDS.

Route.	Depth of wear.	Total No. of car passes.	No. of cars per $\frac{1}{16}$ in. depth of wear.	Operating speed.
Parkside	4/16 in.	1,517,821	379,455	Medium
"	7/16 in.	1,517,821	216,831	Fast
North Adelaide	6/16 in.	2,174,450	362,408	Medium
Henley	6/16 in.	1,287,981	214,663	Fast
King William St., City	9/16 in.	6,620,064	735,562	Slow
" " "	7/16 in.	5,184,209	740,601	"
Unley	7/16 in.	1,377,484	196,783	Fast
"	3/16 in.	1,377,484	459,161	Slow
Kingswood	2/16 in.	770,270	385,135	Medium
Hutt St., City	6/16 in.	2,150,818	358,469	"
Henley	9/16 in.	1,660,513	184,501	Fast

The number of car passes per 1/16 in. depth of rail wear shown in Table II, varies between 184,500 for fast speeds to 740,600 on slow speed tracks and also proves that fast traffic is conducive to more rapid rail wear. Any suggestion to reduce operating speed as a means of prolonging rail life would obviously be ridiculed, so that other methods must be adopted to achieve this purpose.

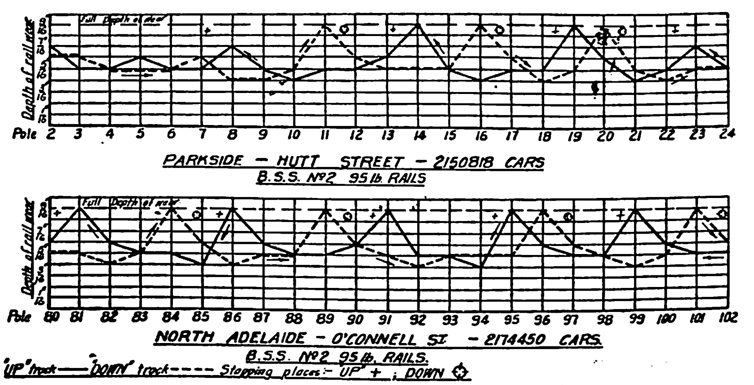

Fig. 3.—Diagrams of Rail Wear, Parkside and North Adelaide Routes.
Showing excessive wear approaching stopping places.

The study of numerous rail wear diagrams shows that in places where the outer rails of double tracks were originally constructed lower than the inner rails (1 to 1½ in.) to conform to the camber of the existing roadway, the wear on the lower rail was always greater than that of the higher due to the greater load on the lower rail. It is, therefore, necessary to lay both rails level during construction or renewal work, even if it necessitates the making up of an additional portion of the roadway.

Acceleration and Deceleration.—Diagrams reveal abnormal rail wear approaching and leaving stopping places (approximately 100 ft. each way) compared with normal wear between these places. This is due to sudden braking and rapid acceleration of trams. The wear is more pronounced approaching stops and was particularly noticeable when magnetic brakes were in general use.

The graph, Fig. 3, shows that along Hutt Street, City, the rail wear for 2,150,818 car passes averaged 6/16 in. between stopping places, but approaching these places in every instance the rails were worn out, i.e., 9/16 in. worn. A similar condition existed in O'Connell Street, North Adelaide, the wear between stopping places averaging 5/16 in. for 2,174,450 car passes, but approaching these places the rails were also 9/16 in. worn.

The wear of the rails immediately leaving a stopping place, due to acceleration, is not as great as that approaching, but appears to be about midway between this and normal wear between these places.

The "in situ" hardening of the rail surface approaching stopping places where the wear is excessive, is worthy of consideration, as the rails thus hardened may then outlast the other rails and delay renewal work for a few years. Alternatively, the use of medium manganese or alloy steel rails approaching such stopping places may be worthy of consideration during future reconstruction work.

Wheel-Rail Contact.—In order to obtain the maximum of service from the rail, good wheel-rail contact is essential, otherwise rails are subjected to loads which exceed the elastic limit of the steel, resulting in detrusion, permanent deformation, corrugation, etc. Unfortunately it is impossible to secure good contact on all rails throughout a system where different sections are in service, and where tyres and rails are in various stages of wear.

It has been observed, by the examination of numerous diagrams of worn rails and wheel tyres, that there appears to be a natural wearing shape in Adelaide, as both rail and tyre wear to a radius of, approximately, 12 in. on a slope of about 1 in 21, the rail convex and the tyre concave. This wearing shape possibly varies on different undertakings, owing to variations in rolling stock and rail design, the effect of different brake blocks used, and operating conditions generally.

Under present conditions good contact is not always obtained between new tyres and all sections of new rails. It requires several months under traffic before the rails wear to the required shape. Similarly, good contact is not made between new tyres and worn rails or between worn tyres and new rails, but contact is generally good between worn tyres and worn rails.

Increased contact area may be obtained by :—

1. Increasing the width of wheel tyres.
2. Increasing wheel diameters.
3. Grinding or scrubbing rails to an even profile.
4. Designing rail and tyres to natural wearing shape.

In Adelaide the standard tyre width of 3 in. was increased to $3\frac{1}{2}$ in. for type "H" cars. Wheel diameters were also increased from $26\frac{1}{2}$ in. on type "F" cars to $33\frac{1}{2}$ in. for type "H" cars.

It is the practice in Adelaide to scrub the surface of new rails before a track is opened for traffic, as there are surface defects which should be removed before these are exaggerated. This should also result in better wheel contact.

It is reasonable to assume that if rails and wheel tyres were designed to the wearing profile previously mentioned, good contact would be provided from the outset and the life of the rail thereby prolonged. With this object in view, the 104 lb. grooved rail, Fig. 4, was designed by the author for use along tangent track, or as an "outer" or "high" rail on curves, under conditions existing in Adelaide.

In addition to providing excellent contact with the majority of tyres in service, good contact should be obtained near the centre of the rail head with new tyres (Fig. 4). The height of the rail conforms to the existing rails in service and could be used for replacement on concrete foundations, etc., without disturbing such foundations. The web of the suggested rail is stronger than that of the B.S.S. No. 6 (96.4 lb.), and the centre is placed $\frac{1}{4}$ in. nearer the centre of the rail head. This should prevent distortion and give additional resistance to the head turning over when the rail is in an advanced stage of wear. The rail has been designed so that the 102 lb. fishplates can be used at the joints. These are much stronger and more suitable for welding than the B.S.S. fishplates.

Rail Corrugation.—The most perplexing factor in the problem of rail wear is that of corrugation of the surface. Many conflicting theories as to the cause of corrugation have been advanced from time to time. These are possibly based on the predominant factor existing on the property concerned, but as these theories differ it is possible that they represent different phases of a problem containing many variables. If this be a true conclusion, many of the paradoxes and anomalies can be readily understood.

W. W. Beaumont, Chairman of the Committee investigating (*Railway Gazette*, 24th February, 1922) submits the theory.—"The cause of corrugation is the compression of the material of the top surface of the rail head by the rolling upon it of the heavily loaded tramcar or railcar wheels, and suggests that the pressure may reach 150 tons per square inch. As the loaded wheel rolls along the surface it presses before it a wave of compression. The limit of elasticity and toughness of the material limit the length of this wave of surface deformation. The rolling wheel, therefore, rises upon the crest of the wave at this wave length limit, and this recurrent operation forms the corrugation with its hard crest and softer part between the crests, and with pitch or distance apart, determined by the elastic limit of the material at the rail surface."

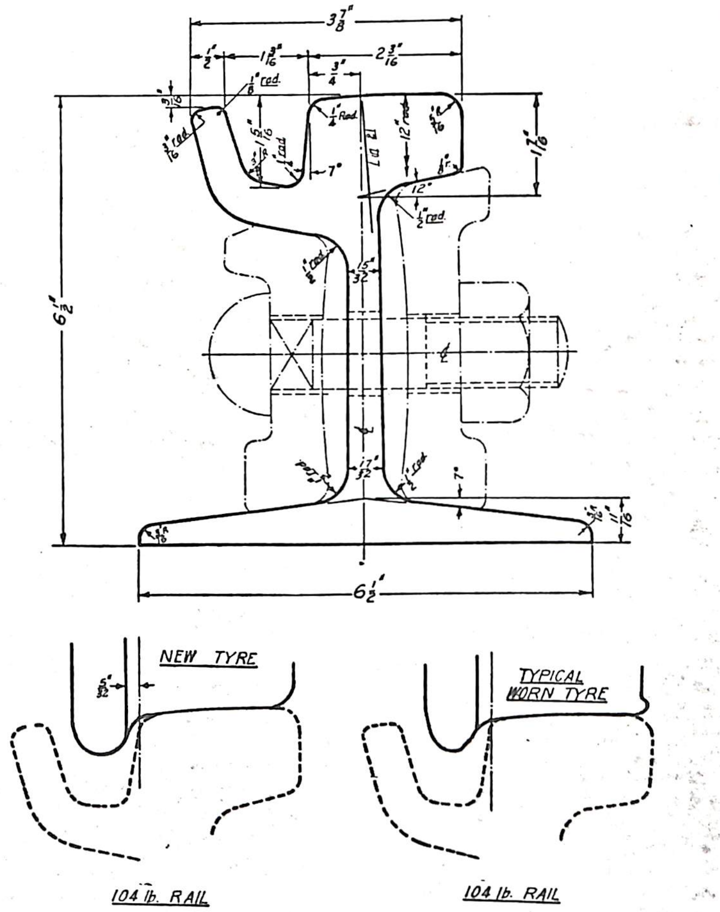

Fig. 4.—Proposed 104 lb. Rail.
Showing wheel contact with new and worn tyres.

With reference to the formation of corrugation, it has been observed in Adelaide that :—

1. Corrugations appear on new track from three to six months after rails are in service.
2. The outer rails of large radius curves soon corrugate. On curves of less than 100 ft. radius corrugations are rare, possibly due to slow speed of cars.
3. Corrugations are more pronounced on "down" grades than on "up" grades.
4. High speed sections of track corrugate more than low speed sections of the same track.
5. Corrugations are rare on open ballast track with Tee-head rails, through parklands, etc.
6. Sandberg "in situ" rail hardening does not prevent the formation of corrugation, but definitely retards this.
7. Manganese crossings (12 to 14 per cent. manganese) are subject to corrugation.
8. Rails ground with a rotary grinder soon corrugate again.

Corrugation Removal.—The only method of removing corrugation is by grinding or scrubbing the rails, and the sooner this is done after appearance, the less will be the damage done to the track. In Adelaide, the deeper corrugations are removed with

rail corrugation between Victoria Embankment and Kingsway

a Woods-Gilbert rail grinder which operates two 24 in. + 2 in.

these plac

grinding wheels. The machine is worked five nights per week

and treats approximately 500 ft. of single track each night at a cost of 1½d. to 2d. per foot of rail, the length treated and the cost depending on the depth of corrugation.

During grinding operations care must be taken to keep the wheels properly dressed, as failure to do so may result in the rail surface being ground hollow.

Grinding should be carried out to give the maximum area of wheel-rail contact. For this purpose the rails are "scrubbed" after the deeper corrugations have been removed.

Rail Scrubbing.—In addition to "polishing" the rails after grinding, the rail scrubber is used for removing "shallow" corrugations. The machine consists of a water sprinkler with a frame on each side containing four 10 in. × 4 in. × 2½ in. scrubbing blocks. The pressure on the blocks is regulated by an air valve from the driving platform at 30 to 40 lb. per sq. in., and a uniform speed of, approximately, 15 m.p.h. is maintained. Water is played on the rail surface while scrubbing is in progress. A length of, approximately, 600 yards of track is treated when working at night, but on day shift the machine is operated in traffic between crossovers, the number of trips to complete the work depending on the depth of the corrugations. Costs of scrubbing vary between 0.25d. and 0.75d. per foot of rail.

The effective life of the rail is undoubtedly decreased by grinding and scrubbing, but if corrugations are neglected they reach a stage where battering commences and deterioration is rapid, resulting in loose track, noise, and discomfort to passengers.

Some idea of the loss of serviceable life of the rail due to grinding and scrubbing, may be gained by referring to Table II, which shows the average number of car passes per 1/16 in. of rail wear to be between 184,000 and 740,600, so that the removal of 1/64 in. of rail head would mean the loss of between 46,000 and 185,000 car passes. Anything tending to prevent or retard the formation of corrugation would, therefore, assist in prolonging the life of the rail.

Methods of Mitigation.—Although it is impossible to prevent entirely the formation of corrugation on any undertaking, there are, however, various methods of controlling this destructive evil which should be adopted where possible, among them being :—

1. Grinding or scrubbing rails in the early stages of corrugation before damage is done to the track and rolling stock.
2. Maintenance of joints before battering commences.
3. Maintenance of wheel treads to avoid flat spots and other causes of impact loads.
4. Sandberg "in situ" hardening of rails on main lines where this expense is justified.
5. Maintenance of good level, gauge, and alignment of track.
6. Increasing the wheel-rail contact area.
7. Decreasing unsprung weights and total wheel loads.
8. The use of better quality rails.
   A steel with a higher elastic limit in order to withstand impact blows without permanent deformation, and a high work of rupture to withstand abrasion. Medium manganese and alloy steel.

It is impossible to carry out all of the above-mentioned items on any tramway system, as there are so many other operating costs to be considered, but the adoption of anything which will prevent, or at least retard the formation of rail corrugation, is a move in the right direction.

Corrosion.—Considerable trouble has been experienced in Adelaide due to the corrosion of rails and fastenings along tramway tracks in the limestone area of Enfield and Prospect.

In many places the flange of the rails had badly corroded, leaving only about 1½ in. at the centre, which was not being held by the dogspikes. In other places the web of the rail had also corroded through.

It was necessary to renew over two miles of single track with approximately 75 per cent. of life remaining in the head of the rails, owing to the corrosion of the web and flange.

During the renewal of the above-mentioned track, it was noticed that rails were in excellent condition where tarred macadam had been used around the web and flange of the rails at turnouts, but immediately leaving this tarred section the rails were badly corroded again.

In 1932 Sir William Goodman, Chief Engineer and General Manager of The Municipal Tramways Trust, arranged with Dr. W. A. Hargreaves, M.A., B.C.E., D.Sc., to investigate this problem of corrosion.

Small sections of rails, samples of soil and water from Enfield, and samples of soil adjoining rails from localities unaffected by corrosion, were examined and analysed by Dr. Hargreaves. In his report to the Chief Engineer and General Manager, dated 12th September, 1932, under the heading of "General Conclusions," Dr. Hargreaves states, *inter alia.*—

> Although moisture and oxygen are usually regarded as the principal factors in corrosion, it is known that pure iron is not attacked when in pure water containing dissolved oxygen. Hence some other factor or factors is essential. Dr. Stokes (*Chemical Engineering and Mining Review*, August, 1929) draws attention to the negative-ions other than OH-ions, and states, "It is the presence of both negative-ions and dissolved oxygen, neither of which produce rapid corrosion alone, that produces conditions most favourable for the rapid destruction of iron. Probably equal stress should be placed upon both."

Further, Dr. Hargreaves stated—

> My own view is to place the greatest stress on the negative-ions under the conditions we have under review, and consequently we regard the concentration of chlorides and sulphates in the ground moisture as being most active in maintaining corrosion.
>
> All the elements of an electrolytic cell are present. Contact of dissimilar metals or eutectics, impurities in the iron, or oxygen in contact with the iron, set up differences of potential in the presence of moisture containing oxygen and a sufficient concentration of electrolytes.
>
> At the sites of corrosion on the Enfield line these factors are present in a greater extent than at any other sites dealt with and, in my opinion, the causes of the greater corrosion at these sites is thus disclosed.
>
> That these sites are associated with the limestone areas is, I think, explained by the theory that the so-called limestone has been deposited from highly saline waters, and the soils in the vicinity are, in consequence, likely to be more highly charged with chlorides and sulphates than at other districts where the limestone is not found.
>
> The remedy is to keep the rails from contact with such saline soils if possible, and to protect the rails as far as is consonant with cost by means of an adherent impervious film, such as tar, non-porous paint, special oxidization treatment, to limit or prevent access of oxygen.
>
> Where it is known that highly saline soils are to be met with it may be feasible to give special attention to ballasting at those places, even though it may involve extra cost.

For many years it has been the practice in Adelaide to paint with tar all tie rods and dogspikes, and in the limestone areas the web and flange of rails are also painted when reconstruction work is in progress. An inspection of the rails along track opened subsequently for repacking purposes, has shown this treatment to be satisfactory.

Track Irregularities.—Much of the uneven and excessive wear of rails is due to track irregularities, and it is, therefore, essential that all permanent way work in progress should be carefully supervised.

The rails should be laid to the same level, and every effort made to obtain long uniform grades and good alignment, as this will give a smooth path to the tramcar and thereby minimise car nosing, lateral swaying, etc., which greatly contribute to uneven rail wear. Of equal importance is good track gauge. Tightness of gauge causes overriding of the wheel, and consequent reduction of contact area, and the wheels soon wear away a portion of the head of the rail. Wide gauge wears away the check.

Rail Joints.—It has been stated that the life of the joint determines the life of the rail. Although this is not strictly correct, many rail and track troubles are attributed to bad joints. The Thermit welded joint is undoubtedly the best type in existence. This joint, efficiently made, provides a continuous smooth running surface which requires no further attention. More than 17,000 Thermit joints were made during the original construction of the tracks in Adelaide and the majority of these are in good order after more than 30 years in service.

When the importation of Thermit was prohibited during the last war, the electric welding of fishplated joints was introduced, and much experimental work was carried out, which has been justified by the excellent joints in service to-day.

Owing to the difficulty in obtaining fishplates during war time, and in order to conserve present stocks, an electrically welded joint was designed in Adelaide for the tramway extension to Cheltenham (Fig. 5). The rails were temporarily plated and the flanges welded to a steel soleplate 18 in. × ½ in. A steel shim, ½ in. in thickness, was inserted between the rail ends, and this was welded to the flange of the rails and vertically to the web. The gap at the head was built up with M.S. electrodes to within ¼ in. of the surface, and then with special spring steel wire No. 8 gauge to the surface. The joint was then ground smoothly. It is customary to examine carefully and, if necessary, maintain all rail joints in the early stages of service before any hammering or battering takes place, as this causes cars to lurch and sway, resulting in uneven wear of rails near the joints.

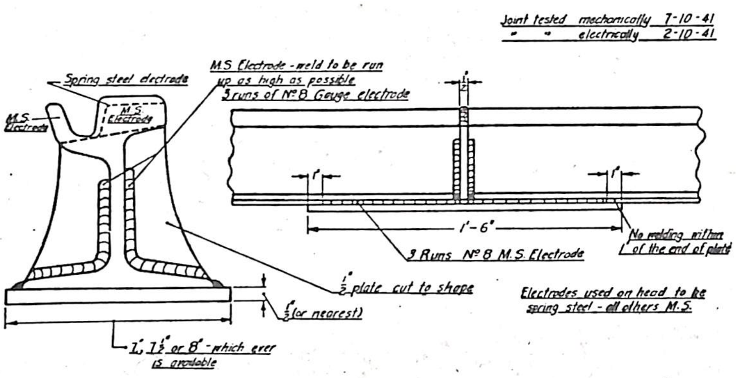

Fig. 5.—Electric Welded Joint, 102.06 lb. Rail.

Debris.—Prior to the advent of bitumen and the construction of improved types of roadway, it was very difficult to keep rail surfaces and grooves clean. Water sprinklers were used to clean the rails but the grooves soon filled again.

It was particularly noticeable that Tee-head rails through parklands showed less wear than grooved rails on the same track. The excess wear shown on the grooved rails may be mainly attributed to the accumulation of dust and grit on the rails, which has an abrasive effect under tram traffic. This was more noticeable when the water bound macadam roadway predominated, but with the modern type the dust nuisance has been reduced to a minimum.

Track Foundations and Drainage.

The importance of constructing a good, well-drained foundation in all track work, cannot be too highly stressed. If the foundation is not properly constructed or the drainage is bad, sleepers soon work loose, levels and joints are upset, and the rails are subjected to uneven wear.

The many types of track foundation may be summarised under two headings, i.e., "Rigid," and "Resilient."

There has been much controversy on the advantages and disadvantages of both types.

It is essential with the rigid type, where sleepers are used, that the rails be continuously supported, as otherwise they quickly "cut in" to the sleepers, the fastenings work loose and the road surface becomes broken.

The concrete foundation, although more costly than the ordinary ballast type, is more durable, and rails can be replaced when necessary at a comparatively small cost. The road surface is held better and requires very little maintenance.

The initial cost of the ordinary metal ballast foundation is certainly less, but as this type generally costs more to maintain and the work of renewal is more costly, it is questionable as to whether this saving—approximately £40 per chain of single track in Adelaide—is economical.

Sleepers generally last longer embedded in concrete, and there are many which have been in service over 30 years in Adelaide in good condition to-day.

Good drainage is essential in all track construction work, and track drains are provided at frequent intervals and connected to storm water drains where possible. Water is recognised as the most destructive agent in track work, and many track troubles are averted if the road bed is kept dry.

The cement grouted foundation is now standard practice in Adelaide for city and busy suburban lines, and in places where the subgrade is bad, and the flexible type is used where open ballast work is possible and on outer area tracks, where this type will last for many years.

Sandberg "In Situ" Rail Hardening.

This process was invented by the late Mr. C. P. Sandberg, of London, in 1916. Owing to the shortage of labour and materials in England during the last war, engineers were only too ready to investigate this new method of prolonging rail life.

The process is based upon the susceptibility of medium and high carbon steel to heat treatment. The apparatus, consisting of an oxy-acetylene plant mounted on a truck, is propelled slowly by hand, whilst the flames from a special blowpipe impinge on the head of the rail, heating a portion of the head to a temperature above the critical range. Jets of water are sprayed on the rail immediately behind the blowpipe, quenching and cooling the treated portion, producing a hardened section to a depth of, approximately, 3/16 in. The greater portion of this is martensitic, i.e., of maximum hardness and wearing resistance, becoming softer as the troostitic, sorbitic, and eventually the normal pearlitic structures are reached.

The blowpipe nozzle is provided with two apertures, or jets, approximately 9/16 in. apart. The oxy-acetylene cones are brought as close to the rail surface as possible without actual contact and allowed to remain until the operator, observing the formation of the discs of orange-red rail surface, witnesses the merging of the discs. The truck is then propelled slowly by hand so that the band of colour so formed is maintained.

The speed, which averaged 30 ft. of rail per hour in Adelaide, must also be regulated to keep a uniform width of colour band. As the speed varies with the composition of the rail, it is, therefore, possible to treat only one rail at a time. Before treatment, any corrugations on the rails must be removed.

To prevent chipping at the joints, the work must be stopped about ¼ in. from the joint. When beginning again after any stoppage, the flame should never be directed upon metal already hardened, but advanced about ¼ in., as failure to do so may lead to cracking of the rail.

The colour band, which is approximately 1¼ in. wide, should also be kept about ¼ in. from the running edge, or gauge line, of the rail.

Description of Plant.—An acetylene generator, six oxygen cylinders, and a water tank, are mounted on a truck with driving gear which can be propelled slowly by hand. The blowpipe and quenching jets are supported by an adjustable carrier, connected to the front of the truck by a hinged bracket. The oxygen cylinders are arranged in two batteries of three and are furnished with three-way connections fitted to valves at the front of the truck. The operator is thus able to turn on the supply from the second battery when the first is exhausted without stopping the work. The blowpipe is fitted with a special twin nozzle and adapter and is operated at a pressure of, approximately, 45 lb. per sq. in.

In Adelaide, a water sprinkler was used to haul the plant between the depot and the work, and to supply the necessary water. A four-wheeled truck was also used for carrying the necessary buckets, spent carbide, etc.

The process was commenced in Adelaide in March, 1928, and a total length of, approximately, 17 miles of single track has been treated.

Costs have been reduced considerably since 1928, owing to the reorganisation of the gang, the use of two machines, costs of materials, and the expiration of the royalty burden.

The cost, from March to December, 1928, using one machine, averaged 27.46d. per foot of rail.—

Labour	6.85d.
Gas (oxygen, carb. and water)	8.50d.
Royalty	7.00d.
Sundries	5.11d.
	27.46d. per foot of rail.

In October, 1930, using two machines, the cost of treatment averaged 15.38d. per foot of rail, the gang consisting of:—

1 Operator in charge.
2 Burner Operators.
2 Wheelmen.
1 Man for attending to the generators and driving the sprinkler.

Costs of the treatment were further reduced in 1933, mainly due to the expiration of the patent, and averaged 9.70d. per foot of rail.

Materials used each night, with two machines working, averaged:—

Oxygen	1,300 cu. ft.
Carbide	224 lb.
Water	1,600 gal.

Although "in situ" hardening definitely prolongs the life of rails and retards the formation of corrugation, it would be uneconomical to harden rails over which there is an infrequent service of cars, as these rails without treatment would possibly last up to 50 years—the approximate life of two sets of sleepers. It is, however, a payable proposition on tracks which are subjected to heavy traffic.

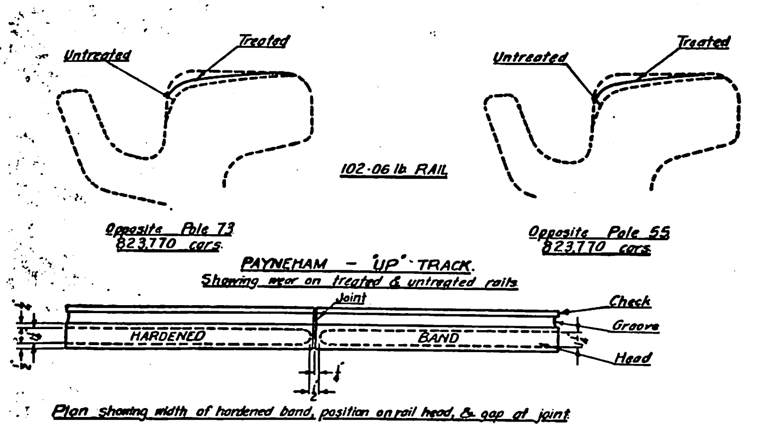

Fig. 6.—Sandberg "In Situ" Rail Hardening Treatment.

During the process of hardening the rails on a section of the Payneham tracks, the outer rail of the "up" track was left untreated for comparison with the other rails. Diagrams of the rails were taken after a period of seven years, 823,770 car passes, and in every case the wear shown on the untreated rail was 3/16 in., and only 3/32 in. on the treated rail, as shown in Fig. 6.

As the treated portion of the rail averages 3/16 in. in depth, it should take, approximately, 14 years to wear down to this depth, but the untreated rail, wearing 3/16 in. in seven years, would have worn 6/16 in. in this time.

The full depth of wear being 9/16 in., the life of the untreated rails under existing conditions in this locality would approximate 21 years, and the treated rails 28 years if left without further treatment, or 35 years if treated again (Fig. 7).

Before commencing treatment, the rails should be carefully examined for unsoundness, corrugations, and defective joints, and a record kept of any unusual features. Corrugations should be removed and all repairs carried out before the application of the treatment. Operators must be extremely careful to see that the colour band is maintained, as failure to do so may result in burning the rail and cause surface flaking.

Curved Track.

Rail wear around curves is more rapid than that on tangent track under similar conditions, and every effort must be made to obtain the maximum of service from the rails. The principal items to be considered are:—

(*a*) The radius to be as large as the locality will permit, with suitable transition.
(*b*) The rails must be properly curved in a rail press, or with a Jim Crow with interchangeable pallets to engage the entire rail section and prevent distortion.
(*c*) The curve to be first laid out and plated so that joints may be made true to curvature.
(*d*) The use of better quality rails, such as regulated sorbitic, intermediate manganese, or alloy steels.
(*e*) The Sandberg "in situ" hardening of the head of the outer and check of the inner rail, if ordinary rails are used.
(*f*) Super-elevation.
(*g*) The application of a suitable grease at intervals around sharp curves.
(*h*) The electric "building up" of the head of the outer, and check of the inner rail, before curve is badly worn.

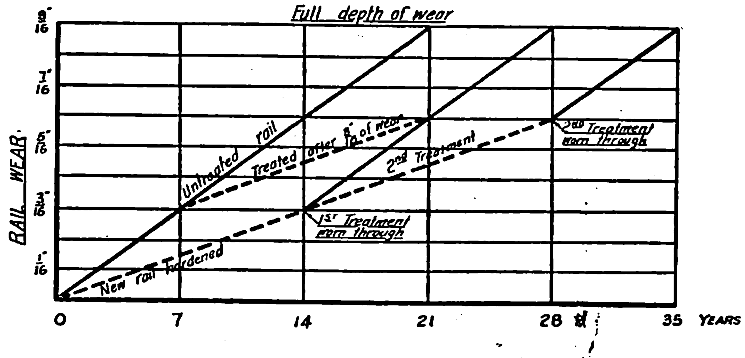

Fig. 7.—Sandberg "In Situ" Rail Hardening Treatment—Estimated Life of Treated and Untreated Rails.

(Based on actual wear diagrams taken on the Payneham route 7 years after treatment.)

The practice of springing rails, i.e., levering them into position, cannot be too strongly condemned, as the rails are liable to return to their original shape, causing kinks and irregularities.

Since the advent of the regulated sorbitic rail, it has been the practice in Adelaide to use this type on curves.

The "in situ" hardening of the head of the outer and check of the inner rail on a curve at Hilton, was carried out about 12 years ago, and the curve is still in fairly good condition.

Electric welding has played a prominent part in prolonging the life of many curves in Adelaide in the "building up" of the head of the outer, and check of the inner rail.

Diagrams of rails, Young Street curves, Kensington, (Fig. 8) show the wear of rails after 960,330 car passes, the portion built up, and the wear after 125,000 car passes.

Although "building up" is a fairly slow process it is not very costly, being approximately £10 per chain of single track in Adelaide, and it postpones the more costly work of renewal for a few years.

To assist in turning the car and to reduce rail wear on curves, it is necessary to elevate the "outer" rail. This is not possible through special work at junctions, and in some places only slight

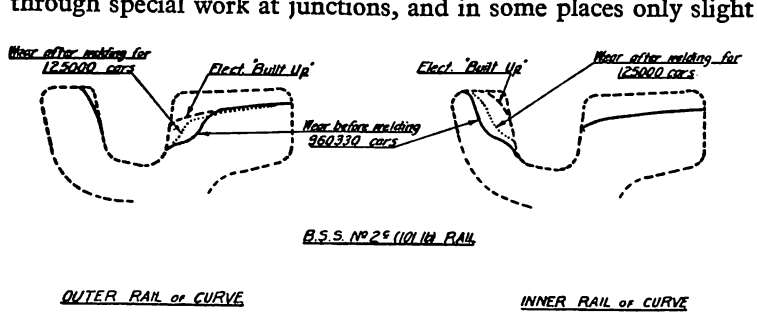

Fig. 8.—Electric Welding—"Building Up" of Head, and Check of Rail, on Kensington-Young St. Curve.

elevation is permissible owing to the contour of the adjoining roadway. In parklands and along private thoroughfares greater elevation is possible, the maximum in Adelaide being 5 in.

The wear of rails on curves is also retarded by the regular application of a special adhesive grease along the "running edge" of the outer, and check of the inner rail. Care must be taken, however, to keep the grease from the rail surface to prevent wheel skidding.

Improving the Quality of the Steel Rail.

Owing to comparatively light axle loads, early rails gradually work-hardened under the rolling loads and had a life of phenomenal length. During the past 30 years, however, axle loads and speeds have increased out of all proportion to the wearing capacity of the rails, necessitating the search, in recent years, for a better-wearing rail steel which will, similarly, be so much in advance of present-day conditions as will enable it to work-harden in the early stages of its life in the track.

This search for better wear has proceeded along three different lines.—

(1) The reduction of the carbon and the raising of the manganese content. (Manganese 0.9 to 1.2 per cent).
This steel has better work-hardening properties than high carbon steel.

(2) The introduction of alloying elements (such as chromium—0.5 to 1.0 per cent. with carbon limited to 0.5 per cent. to avoid brittleness).
Manganese used as an alloy up to 12 to 14 per cent. This has produced a steel with remarkable work-hardening properties but the cost to user is from four to six times that of ordinary rail steel.

(3) The Sandberg Sorbitic heat treatment and regulated cooling of rails during manufacture.
By this treatment a hardened and greatly toughened exterior, reproducing the work-hardened casing of early steel rails, is provided for the rail head.

The Sorbitic treatment (3) is the application to the rail head of a finely atomised spray of water in the form of a scotch mist, and is commenced when the rails are at a temperature of between 800° and 850°C. Immediately the rails are released from the grips after quenching, the web and foot cool more rapidly and the rails curve with the head convex and the foot concave. To avoid an excessive amount of cold straightening, a counter camber is put into each rail, the amount necessary with each type being arrived at by experiment.

The body of the rail is then at a temperature of about 550°C., and the rails are then passed into the Sandberg oven for retarded cooling. The treated rails remain in the oven for about 30 minutes, during which time the temperature is evened out to reduce internal stresses and as a safeguard against internal fissuring. After the temperature has been brought down to approximately 300°C., the rails are passed out on to the end of the hot bank for final cooling, after which the usual operations of straightening, ending, and drilling, are carried out. Prior to the introduction of the "oven," it was necessary that the carbon content of sorbitized rails be kept lower than that of the untreated rails.

Some remarkable results have been obtained with regulated sorbitic rails in tests carried out at four British mills. Tensile tests, taken from the side of the head 7/16 in. below the running surface, which may be expected to give an ultimate stress of 60 to 65 tons per sq. in., will frequently give a yield that is as much as 75 per cent. of the breaking stress. In the zone immediately under the rail head, about $\frac{1}{8}$ in. below the surface, tensometer tests have shown an ultimate strength of 69 to 77 tons per sq. in., and yield stresses of from 60 to 66 tons per sq. in., which are probably the highest yet reached with any description of rail steel whether heat treated, alloy steel, or a combination of both. These very high tensile stresses are associated with elongation percentages of 15 to 11.5 per cent., so that in the zone where the treatment has been most drastic there is still more than adequate ductility.

It is well known that no physical test on steel that has yet been devised, nor combination of tests, gives a complete and accurate measure of the resistance of that steel to the complex punishment to which the rail is subject when in service.

The comparative slight defects due to rolling which, though undesirable, may not be serious in softer rails, may be dangerous in harder steels where they are more likely to be produced owing to reduced plasticity of metal during rolling.

In 1928, trouble was experienced in Adelaide and Melbourne with 102.06 lb. rails manufactured in England. Although the rails had passed the B.S. Specification tests at the mills, several developed cracks at the ends when being unloaded and handled in Australia and always at the same position on the rail. The rails showed a slight imperfection or overlap near the junction of the web and flange on the check side. Sections were cut from various rails and micro-photographs taken and examined.

The fault or overlap was caused in adapting rolls of another section for the rolling of the 102.06 lb. rails, and the authorities concerned were compensated by the manufacturers after their own representatives had investigated the matter in Australia.

It would be an added safeguard in ordering large quantities of rails, to employ a metallurgist to make periodical examinations of the rails, as the above-mentioned rails had fully satisfied the B.S.S. tests.

The Departmental Building of Special Work.

Special crossings, etc., for tramway junctions, turnouts, and crossovers, are usually cast in manganese steel (manganese 12 to 14 per cent.) and are very costly.

A few years ago experimental crossings were built departmentally in Adelaide with ordinary rails, and very good results were obtained in service. Later, point dummies were also built, and many compound crossings and dummies, built departmentally, are standing up well in traffic to-day.

As it is now difficult to purchase cast manganese special work owing to war-time conditions, the whole of the single, double, and triple crossings and dummies required in Adelaide, are made at the permanent way depot.

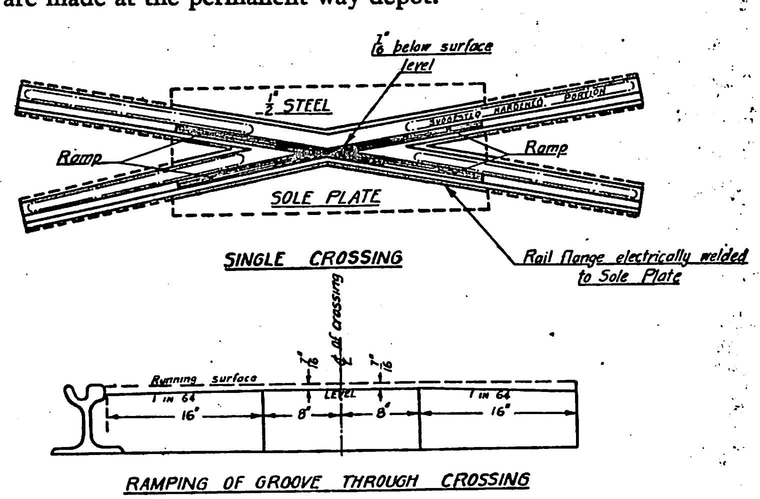

Fig. 9.—Type of Special Rail Crossing as Built Departmentally in Adelaide.
Showing suggested hardening of rail surface and ramping of grooves.

In the case of single crossings, Fig. 9, the procedure is as follows :—

The curved rail is oxy-cut to the required angle and fitted to the straight rail which is carried through unbroken. The flanges of both rails are welded to a steel soleplate $\frac{1}{2}$ in. thick. The grooves are ramped 2 ft. each way from the centre of the crossing so that the wheels run on their flanges over the centre of the crossing. A groove is then ground

Special work is built on a special concrete floor with holding down bolts, and no trouble is experienced in buckling or moving during welding. Each unit is made to the same dimensions as the one to be replaced, and it is therefore unnecessary to renew more than those actually worn out on a junction, and the maximum of wear is thus obtained from the other crossings.

The cost of the electrically welded single crossing is approximately £20, or less than half that of the cast manganese type.

After crossings have been in service for a few months it is necessary to inspect the ramps on the grooves and build these up electrically if required.

The life of the crossing would also be prolonged if the rail surface were hardened from a point near the end of the ramp; as shown in Fig. 9.

Conclusion.

In conclusion, the importance of experimental work during the construction and maintenance of permanent way, cannot be too highly stressed, as results thus obtained are invaluable in effecting improvements on future works. Equally important is the necessity of careful supervision on all work in progress and frequent inspection of tracks and special work in service.

The more extensive use of cement for track foundations and bitumen for surface waterproofing, with the better quality rails available, provide possibilities for securing a better permanent way on which rail wear and maintenance costs will be reduced to a minimum.

Acknowledgment.

The author desires to thank Sir William Goodman, M.I.E. Aust., Chief Engineer and General Manager of The Municipal Tramways Trust, Adelaide, for his permission to present details embodied in the paper.

Aluminium Industry.

Commonwealth Geologist's Views.*

In an address to the Royal Society of Australia, at the Canberra Institute of Anatomy, Dr. H. G. Raggatt, Commonwealth Geologist, said it was pleasing to know that the Government had decided to establish an aluminium ingot industry in Australia. The Minister for Supply and Shipping (Mr. Beasley) had stated that it was proposed to set aside £3,000,000 for the purpose.

Dr. Raggatt was speaking on " Some War-Time Aspects of Australia's Mineral Industry." It was most unfortunate, he said, that the manufacture of aluminium had not been commenced in Australia prior to the war. At that time, however, New South Wales was the only State which had made a survey of its resources of bauxite, the principal ore of aluminium.

In those days the overall costs borne by the aluminium industry in Canada and U.S.A. were apt to be forgotten. It would be wise to remember them today. Canada, one of the great aluminium-producing countries of the world, has no bauxite deposits of any consequence and reserves of high-grade bauxite in the U.S.A. are insignificant. Nearly all the aluminium produced in both these countries is made from bauxite imported from British and Dutch Guiana.

Dr. Raggatt stated that considerable quantities of bauxite, of varying quality, were available in Australia, the highest grade being in Victoria where it is known that there are many thousands of tons of high grade bauxite.

The Victorian Mines Department has one of its boring plants operating in the Boolarra district, and two deposits near Mirboo North have recently [illegible] ... the deposits are easily [illegible]

There are other accessible deposits in New South Wales—running into millions of tons. They occur in two main groups—Emmaville-Inverell and Bundanoon-Wingello, the former being the higher grade. " Though somewhat lower in grade, the Bundanoon deposits might be preferred to the others in New South Wales," said Dr. Raggatt, " because of their nearness to black coal (which is required in the ratio of one ton to one ton of alumina), fabricating plants, and shipping facilities."

There are also considerable deposits of bauxite in Tasmania. The original discovery was made in the Ouse Valley in 1941, and though other discoveries have since been made the Ouse bauxite is the highest grade so far known in Tasmania. The deposits are conveniently situated near coal, water, and hydro-electric supplies.

At Lake Campion, Western Australia, there is an alunite deposit of an unusual type which has created much interest. It is a lake filling containing not less than two and probably more than 10 million tons of alunite mud. The alunite content of the mud is approximately 60 per cent. A plant has been erected for the recovery of a product containing 75 per cent. sulphate of potash and 25 per cent. sulphate of soda at the rate of 5,000 tons per annum, and it is hoped to expand this production over a period of years. The residue from the potash plant will contain about 46 per cent. alumina and 37 per cent. silica. A pilot plant is being erected (which will make use of hydrochloric acid generated in the potash plant) with the object of finding out whether alumina suitable for the manufacture of aluminium can be prepared from this residue.

*This article has been made available by the Department of Information, Melbourne.

To the Editor.

Status of The Engineering Profession.

Sir,

I would like to add my support to the views expressed by Mr. J. Downes in the September-October issue of The Journal.

I consider that no apologetic tone is necessary in suggesting that The Institution should be vitally concerned in the reimbursement of its members. Whilst I would be the last to infer that the only reward of the professional engineer interested in his profession is hard cash, the fact cannot be gainsaid that by far the greater proportion of engineers work for a living, and the living they receive in return for their work is primarily controlled by the moneys they earn.

Some time ago my advice was sought by a friend in one of the more affluent professions as to the future that may lie before his youthful son, an aspirant to professional engineering. Upon outlining the work the lad may be expected to do and the salaries he may receive in the normal course of events, my friend expressed the opinion that engineering would undoubtedly be a fascinating hobby to a man of independent means but was not by his standards a reasonable means of livelihood—with this viewpoint I was reluctantly compelled to agree.

If The Institution continues a policy of disinterest in the financial welfare of its members, it runs the risk of becoming a body merely of academic interest, whilst other organisations far less worthy, and in some cases of rather suspicious antecedents, will continue a trend, already marked, and capitalise on the situation, perhaps to their own benefit, but certainly not to the benefit of the engineering profession or the future of engineering in this country.

Status cannot be dissociated from salaries, and the lack of recognition of the profession must be attributed in general to the engineer himself, and in particular, to the senior members and their influence in the government and semi-governmental authorities which dominate the profession in Australia.

Whether we like the present trend or not, industrial organisations, unions, or whatever they may be termed, are one of the predominant influences in this country and there is no evidence pointing to any diminution in this regard. It may appear sacrilege to mention unions and The Institution in the one breath. The name, however, does not matter: it is the organisation and concerted effort which counts. Having this knowledge, we are faced with the alternatives of utilising it or of being used by those who do so.

In The Institution we have the basis of proper organisation of the engineering profession, organisation which can be used for the welfare of its members and accordingly for the welfare and advancement of engineering science. Far better to use it than mourn it.

Yours faithfully,

G. R. Goffin,

Chartered Engineer (Australia).

Brisbane, Q'land.

22nd December, 1943.