General Meeting of the Institution
HELD AT
The Institution of Electrical Engineers

Wednesday, 13th December, 1933.

The President (Mr. W. CHALLIS) in the Chair.

The minutes of the last meeting having been read and confirmed, and Mr. R. J. F. Harland, a member present for the first time, presented to the meeting.

The **President** said that they would remember that at the last meeting he appealed to members to send in subjects suitable for papers to be read before the Institution. He was pleased to say that, as a result of that appeal, they had now sufficient for up to the end of 1934. If any gentleman cared to put forward a paper, for reading after that date, the Council would be only too pleased to receive it.

The **President** then called upon the Hon. Secretary to read a paper by Mr. C. W. Prescott (Member) " Railway Signalling in Australia " and said that the meeting was very fortunate in having present that evening two or three members who had been associated with railway working in Australia.

Railway Signalling in Australia

By C. W. PRESCOTT (Member).
(*Inset Sheets Nos.* 1-2).

We are told by those who have studied these matters that, so far as geological characteristics, flora and fauna are concerned, Australia is several aeons younger than other parts of the world including Britain and the United States of America. Large tracts of coal have not had time to turn black, some of the animals have not had time to make up their mind to live on land or in the water or to be mammals or the opposite, and many of the plants, by shape and other characteristics, indicate that they have recently survived in an earth not yet completely cooled off. Even the politicians who are in power are considered by those who are *not* in power to be far from maturity ! !

However true these statements may be, Australia has kept pace with, and, in some cases, led the rest of the world in the art of Railway Signalling and, with generous assistance from various sources, the Author has prepared the following notes in the hope that they may prove of interest to other Members of the Institution.

The history and special problems of each State would provide ample material for individual papers and the Author ventures to hope that the Institution may have other papers by Australian Members who are better qualified than he is for the task.

By way of introduction it may be stated that the Continent of Australia is practically 33 times the area of Britain. The majority of the countries of Europe could fit comfortably within its boundaries. It is roughly 2,500 miles from East to West and 1,400 miles North to South and a journey from London to Melbourne *via.* Suez is about equal to a voyage around the coast line.

About 40% of its area is in the tropics but winter sports may be enjoyed at Mt. Koscuisko and Mt. Buffalo.

The population is about one-seventh that of Britain or approximately 6½ millions. Of these, about 3 millions are in a few cities and towns, separated by considerable distances. The train journeys between the capital cities are as follows :—

Brisbane to Sydney	...	613 miles.
Sydney to Melbourne	...	590 ,,
Melbourne to Adelaide	...	483 ,,
Adelaide to Perth ...	...	1,685 ,,

Thus, in travelling by train from Perth to Brisbane, 3,372 miles are traversed or only about 200 miles less than the distance from Liverpool to New York.

It was stated recently that the British Railways employed directly approx. 1/75th of the population or supported about 1/25th. Corresponding figures for Australia are roughly 1/69th and 1/23rd respectively. The total employees per mile of railway being approx. 30 for Britain and 3.4 for Australia. Table 1 gives some further data which may be of interest.

Through the courtesy of the Commissioners and Officers of the systems concerned the data embodied in Table 2 has been obtained. Although this is far from complete as to many details, it clearly indicates that the policy of the Administrations is to provide a maximum of protection to the users of the railways.

The dates given indicate that none of the systems was slow to take advantage of improved safety devices.

It is not possible, in a paper of reasonable length, to deal adequately with such a big subject as the signalling on the Australian Railways, even if the Author were qualified to do so. The following remarks will merely draw attention to certain points which seem worthy of note. There will probably be sins of both omission and commission and if so it is hoped that these will be corrected either in verbal or written contributions to the discussion.

The Signal Engineer reported directly to the Commissioners in three States until a few years ago, when financial considerations caused changes in two cases. At present the Chief Engineer controls the Signal Dept. in all States but New South Wales. In West Australia the Electrical and Signal Engineer is responsible to the Chief Civil Engineer for all safe-working apparatus such as signalling, block instruments, electric staff, also telephones and telegraphs, electric lighting, etc. The State is divided into six Districts and a District Electrical Supervisor has charge of each district. Some further remarks on West Australia are quoted in Appendix A.

In Victoria and South Australia and on the Commonwealth Railways the Signal and Telegraph Engineer controls signals, telegraphs and telephones, as well as certain station lighting, and reports to the Chief Engineer. Traction bonding also comes under his jurisdiction in Victoria.

In New South Wales the Signal Engineer is responsible directly to the Commissioner for all signals, traction bonding, telegraphs and telephones.

The Queensland Railways have a Signal Engineer and an Electrical Engineer who share, under the Chief Engineer, the responsibility for the apparatus mentioned above; it is the Author's understanding that the Tasmanian organization is on similar lines.

With the increasing recognition of the valuable part signalling can play in improving the earning capacity of the Railway it is anticipated that the status of these officers will reflect the importance of the department they control.

Traffic conditions, which vary between one train per day and 30 trains per hour, are to be found on the railways in Australia and therefore there are examples of almost every degree of signalling.

Mechanical signalling methods in general follow standard practice; channel rodding is used in at least two States, temperature variations necessitate careful attention to compensation. In West Australia the variation is from below freezing to 112 deg. F. in the shade.

Double wire working is in use to a small extent in at least two States. Catch handle locking is more largely used in South Australia than in other States though the Victorian practice of applying electric locks to the cam of their standard mechanical locking frame gives much the same effect so far as strain on the lock is concerned. Other States apply the lock to swords attached directly to the lever.

Mechanical semaphore signals are of the lower quadrant type, there being no mechanical upper quadrant signals. The centre balanced arm is used all over Victoria and for certain special purposes in New South Wales. The majority of electric signals are upper quadrant and three-position; pointed, square or fish-tailed as required. Yellow fronts are used for distant signals in Victoria and plain black backs on all power signals in South Australia and Victoria. Others have red front with white band and white back with black band. Lighting is by oil or electricity according to economic justification. It is believed that coal gas is in use in certain places, but the Author is not aware of any cases of the use of acetylene gas. Chimneyless burners have been used with success in South Australia. Power signals are of the top-post type mounted on tubular poles; lattice iron, ferro-concrete and wood being used for mechanical signals.

Wood is avoided where possible on account of trouble experienced from white ants. Rocker shaft lead outs are in use in Victoria and South Australia. Signal arms are electrically repeated in the cabin where required. Thermostatic contacts to prove oil lamps alight are not general.

The first power interlocking was installed at Brisbane in 1904. Three electro-pneumatic frames controlled 130 signals and 80 point layouts. Lock bars were retained, signals detected through points and D.C. track circuits used for control. Other early users of the track circuit were Victoria 1895, West Australia 1900, South Australia 1912, and New South Wales 1905. D.C. track circuits were used for control in Victoria in 1904 in conjunction with lever locks and reversers. A very satisfactory type of reverser was designed by a member of the staff and is illustrated in figs. 1a, 1b and 1c. It was used first on D.C.; an A.C. magnet was developed later. The fact that Victoria has 680 reversers in use and other States over 500 indicates the extent to which this valuable form of protection is employed.

It is conceded by many that the most useful function of the track circuit is the continuous check on conditions permitting a signal to stand in the "clear" position, and the instantaneous reversal of the signal to the "stop" position if those conditions cease to exist. In mechanical installations the use of a reverser in conjunction with track circuits would seem to be the cheapest way to get the maximum safety, since it is more than equivalent to a lever lock. Visual indications of the state of the track are also of great assistance.

The large electro-pneumatic installation in Sydney Central Station was the second power interlocking and was brought into use in 1910. The electro-pneumatic area extends for approx. four miles on the four-track Illawarra line and 8 miles on the six-track main suburban lines and continues on the latter lines for a further five miles. The original frame in Sydney Station Yard has since been replaced by a more modern machine built by the Railway's Signal Dept. to the general design of the all-electric frames, two of which were brought into use about 1917.

Signal aspects were little altered in either Queensland or New South Wales when power working was introduced and although three-position upper quadrant arms were used from the first, in the latter State on the electric signals, the night indications did not differ from those of the mechanical signals because the signal was fitted with one red and two green roundels and a lower light, which could display either green or red, was added. The arm was therefore three-position but the light two-position. This gave night aspects of red/red, green/red and green/green, according to conditions ahead.

In 1915 the all-electric power interlockings at Adelaide Station were brought into service and this was the first installation in Australia, and indeed in the British Empire (outside of Canada), to use speed-signal aspects. The decision to adopt these aspects was reached after much discussion and they have given every satisfaction. Only the running signals were semaphore, all others being dwarf signals with white enamelled (Relph) discs with two or three roundels and a vermillion arm. Running (high) signals and certain dwarf signals were motor operated, the others by solenoid. Dynamic indication was used for points and motor operated signals. The plant was operated on 110 volts D.C., dwarf type signals mounted on short poles were used for platform starting signals ; otherwise the work followed the standard American practice of that day.

The remodelling of the signalling on the Melbourne suburban lines in connection with electrification started in 1915 and gave rise to the placing of some of the largest contracts for A.C. apparatus known up to that time. Members will be acquainted with many of the details of this work and it is only proposed to mention a few points of note ; always bearing in mind that this work was carried out nearly twenty years ago.

The conversion of a great number of D.C. track circuits to A.C., the re-spacing of signals for closer headway and the alterations in position to avoid obstruction to view by overhead structures were essential to the maintenance of safety and the success of electric train operation. It was decided to install an up-to-date system giving a maximum of safety and traffic facilities. The track layout was such that the power operation of points was not justified in the majority of cases ; in fact the first power interlocking was not brought into use until about 1923, although electric signals, continuous detection, etc., etc., were in use from 1917. Speed-signal aspects were adopted after much consideration and these were fully described in previous papers before this Institution.* Complete immunity from interference from the D.C. traction was sought in an all-A.C. system, shielding transformers were interposed between line wire and the hold-clear magnets on signal and train stop mechanisms and motors and relays were of the induction type. On single-rail track circuits chatter and saturation from D.C. were prevented by the use of shielding reactances which caused any D.C. to divide equally between the two halves of the windings in opposing directions and neutralise any magnetic effect. The shunting was assisted by using high impedance bonds of a large size and thermal regulators as current limiting resistances. The integrity of the tripping head of the train-stop arms was checked by the signal circuits for the first time.

Although the points were not power-operated, all the safety features and facilities of modern power-interlockings were pro-

* *e.g.* : that by Mr. G. H. Crook, Proceedings, 1931, Part I., p. 122.

vided. Standard mechanical levers operated the points through rodding and the electric signals through contacts, and were equipped with latch contacts and lever locks, indicating lights, etc. Facing point lock bars were eliminated and continuous detection through the medium of " SS " or point detection relays was provided. The now familiar pole-changing circuit was used, the relay wires being short circuited on one another when the points were unlocked and the shorting contacts used alternately in the operating circuit to prove their integrity. The controlled elements of the relays were wound for operation on 250 volts. so that they could not be picked up by contact with other wires in 110 volt circuits. The individual point detection transformers had a drooping voltage characteristic to prevent one transformer operating more than one relay.

Improvements developed by officers of the department were embodied in the point detectors which allowed the separate checking of four switch points and the short circuiting mentioned earlier.

The switch and lock movement used was a re-design, by the officers of the department, of the Garber movement. With a rod travel of approx. 9-in. the points were unlocked, thrown and locked again. Fig. 4 shows the arrangement of apparatus at a point layout.

The use of an electric plunger lock at the points was not considered necessary but this type of lock has been used on electro-pneumatic point layouts in New South Wales for many years.

The speed of trains accepting a low-speed (10 m.p.h.) signal was checked by a time element relay, a special track circuit being provided where necessary. An "A," illuminated when a signal with a lever control was to be treated as an automatic, was also used.

The signal supply was at 2,200 volts, 25 cycles, distributed by ring mains with three small oil switches (one with overload trip and two non-automatic) at each tapping. An interesting development was the use of a sparkgap in the cable earthing the overhead structures to the rails. This device remained an insulator up to 150 to 250 volts, above which it broke down and connected the structure to the rail. This scheme reconciled the conflicting desires of the Electrical Engineer to prevent a dangerous condition arising in the event of a 1,500 volt insulator breaking down, and of the Signal Engineer to minimize unbalancing and to obtain a maximum shunt on the track circuits.

Electro-mechanical installations, in which electric locking frames are interconnected with mechanical levers for moving the points, have been used in Victoria, the first being put into service at South Yarra about 1916 and two others in later years.

This system has many advantages, particularly where one or more points are likely to require power operation at a later date. The mechanical lever is used to apply manual power to the movement of the points only, all-electric and other locking being done on the electric lever. The Author believes this to be an improvement on the practice of attaching locks, circuit breakers, etc., to mechanical levers and, when all costs are taken into account, not more expensive.

Some interesting remarks on Victorian practice are quoted in Appendix B.

New South Wales continuously extended electric signalling with D.C. apparatus and primary batteries as a source of energy. To-day there are 250 miles of double line automatic signalling of this character although in this as in other States (notably South Australia) trickle charging from A.C. lines through rectifiers is largely being used. Economies in apparatus were obtained in New South Wales by adding, to 10 volt signal mechanisms, a contact operated by the hold-clear magnet. Another feature of their practice was the early use of contacts on lever locks which when " made " proved that the locking member had dropped into the locking position.

The first automatic signalling of single lines on the D.C.-A.P.B. (Absolute Permissive Block) system was a short section on the Victorian Railways in 1922 (an A.C.-A.P.B. installation in New Zealand closely followed this) but an extensive section of this type of signalling was installed by the South Australian Railways in 1924 between Eden and Mt. Lofty on the main line to Melbourne. This demonstrated the advantages of this form of signalling from a traffic point of view and it has been extended until to-day 91 miles of line in South Australia are signalled in this manner. In both the Victorian and South Australian installations the automatic signals controlling entrance to the single line stood normally at " stop " and were cleared through approach tracks. They were electrically interlocked with one another so that both could not clear at the same time.

Members will be aware that the name of the system means absolute block for opposing trains and permissive block for following trains. The use of intermediate automatic signals under this system greatly increases the capacity of single tracks when used in conjunction with proper " fleeting " of trains.

In 1925 a section of A.P.B. was put into operation on the West Australian Railways at about the same time as their first section of double line automatic signals. Both these installations gave satisfactory results and certain extensions are under contemplation at the present time.

South Australia's automatic signalling extends from Hamley Bridge South to Adelaide and thence south-east to Tailem Bend. The Brighton and Outer Harbour lines are also signalled.

Victoria also has extended its installations on the main lines as well as on the suburban. Daylight colour-light signals were adopted and are used in recent work. These are of the multi-lens type using the doublet lens combination. Two remotely controlled crossing loops are in service, operated on a circuit designed by the department ; D.C. point machines, suitable for hand operation, are used at these crossings, which were put into service in 1930. An electric interlocking using an 80-lever locking frame is being installed at present.

The Queensland Railways installed about 12 miles of D.C. automatic signals on double line in 1919 but financial considerations have prevented extensions in this State.

The New South Wales Railways electrified the Sydney suburban lines and opened the first portion of the City Railway between 1926 and 1930, the opening of the Sydney Harbour Bridge in 1932 completing the link between the City and the North Shore lines. This entailed an immense amount of work of a very interesting character, as the City Railway and Bridge sections were laid out for a very close headway of trains.

The traction current is 1,500 volt D.C. with overhead catenary construction ; the coaches are of the multiple-unit type and the brakes are controlled on the electro-pneumatic system. The trip cocks reset automatically after a definite time interval and an emergency application on the driver's brake valve. It is not necessary for the driver to leave his cab after being tripped by a train-stop. Multi-lens colour light signals built by the department are used and, because of the short blocks, long range signals were not considered necessary.

The signal aspects are as follows :—

Stop	Red over Red.
Low speed ...	Red/Red/Green (reading downward).
Caution ...	Green/Red.
Medium caution	Yellow/Red. Medium speed through turnout.
Medium ...	Green/Yellow for straight road and Yellow/Yellow for turnout.
Clear	Green/Green.

Train stops are similar in appearance to those in use on the Euston to Watford line (England). In the electro-pneumatic area the motor is replaced by an air cylinder with the controlling valve outside the case. An illuminated "A" denotes automatic signals.

Appendix C is quoted from an article prepared by the Signal Engineer for the "Australasian Engineer" and gives some interesting information on this section.

It is interesting and a little disappointing to note that the retardation used in the calculation of overlaps shows no improvement on that used for similar calculations on the lines in London in 1906, though the speeds are admittedly higher. The Author has previously pointed out that the braking distance is used three times in arriving at the minimum free-running distance between trains, *i.e.*, in the overlap, between "caution" and "stop" signal and between "caution" and "clear" signal.

Isolated electro-pneumatic interlockings were installed at North Sydney, Hornsby and Epping, the latter being without mechanical locking.

The Author once expressed devout thankfulness that locking frames did not breed in captivity but the amount of useable material that becomes available when large frames are replaced is disconcerting.

All States are faced with the problem of protecting level crossings and it is the Author's impression that there are more automatic level crossing signals in South Australia than in the other States. New South Wales and Victoria are well equipped with gates in the Suburban areas, the former have some pneumatically-operated booms. Magnetic wig-wag signals, motor-driven rotating arms, and flashing lights are all in use, the tendency being to standardize on the latter type. Track circuits and rail contacts are both in use.

The majority of D.C. signal installations, except the interlockings, derive their energy from primary batteries of the caustic soda type but in recent years many have been replaced by storage batteries, trickle-charged by rectifiers ; rectifiers have also been connected in parallel with primary batteries, leaving them " floating ". A.C. supplies of 25 and 50 cycles frequency are used in Victoria, 50 cycles in New South Wales and other States except West Australia which has 40 cycles supply.

Batteries are housed in wooden cupboards, concrete huts, or shallow circular wells of concrete with substantial wooden covers. Timber buried in the ground is subject to attack by white ants and iron and concrete are used where possible on this account. Victoria seems less troubled in this way than other States.

Relays are housed in wooden cupboards in the majority of cases but New South Wales has developed a neat type of concrete hut, made from pre-cast parts, and Victoria uses C.I. boxes in the vicinity of Melbourne.

The spark gaps previously described are also used on the Sydney electrified lines. The impedance bonds are of the resonated type but experience has shown that satisfactory results are obtainable in many places without resonating.

The Commonwealth operates the Central Australian, North Australian and the Trans-Australian Railways,the latter being the most interesting from a signalling point of view. Appendix D gives some interesting facts about this line and the small map exhibited shows its extent.

The Tasmanian Railways have no special signalling features, so far as the Author is aware.

The 1932 Year Book states that 31 private railway companies sent in returns as follows :—

State.	Miles of Railway.	No. of Companies making returns.
New South Wales	115.7	8
Victoria	24.9	2
Queensland	265.8	15
South Australia	33.8	1
Western Australia	277	1
Tasmania	141.6	4
	858.8	31

The Midland of Western Australia and the Emu Bay of Tasmania are the principal lines. Many of the others do not carry passengers.

The Author is not aware of any outstanding features in the signalling of these lines.

All States use the telephone to control traffic to a greater or less extent. New South Wales is at present installing a system of train control to cover the whole of the railway system, the more important lines being first dealt with.

The arrangement of the lines does not call for much classification of goods trains and, while some of this work is done by gravity shunting, rail brakes, power-operated shoes or power point operation have not been considered necessary up to the present.

It is hoped that the foregoing, together with the Appendices, etc., will give Members some idea of the work that has been done by the Signal Engineers in Australia. There are few modern methods in use in Britain and America that are not in use in Australia and the progress of each new development is carefully watched in the technical press. There is still a great amount of work which could be carried out with advantage and economy and no doubt, as conditions improve, this will be done.

Mr. Frazer (then Chief Commissioner of New South Railways) said in his 1919 Report : " In the signalling system as evolved in New South Wales, much of the best practice of American railways has been adopted without in any way relaxing the strict standards of safety maintained on British railways, as the result of practice set up by the Board of Trade. This combination of the two ideals has had satisfactory results in producing a system which lends itself in an eminent degree to the special conditions found on the railways of this State." These remarks might also be applied to other States.

It is problematical whether Australia will be able to maintain her position as to modern developments under the conditions that have existed for the past five years. Absence of traffic, curtailment of appropriations and high tariffs, which, with exchange and primage, increase the cost to the railways of signal apparatus, make it increasingly difficult to make new installations or to modernise those which have been installed for some time. Although local enterprise has been encouraged, the relatively small market for apparatus designed for modern quantity production makes the local manufacture uneconomical, both for the manufacturer and the buyer. The greatest refinements and improvements naturally take place in those countries where the demand is greatest and the cost of these in Australia, under present conditions, hampers the progress of the country in this direction.

The design and type of safety apparatus will undergo greater changes in the next ten years than have taken place in the last ten or even twenty years, because of the important new factors that are being introduced into transportation, and it is only by having free access to the results of large scale developments in other countries that Australian Railways can hope to benefit by them as they should.

APPENDIX A.

WESTERN AUSTRALIAN GOVERNMENT RAILWAYS.

Mr. C. A. McCAUL (Electrical and Signal Engineer).

The Electrical and Signal Engineer here is responsible to the Chief Civil Engineer for all safe-working apparatus, such as signalling, block instruments, electric staff, also telephones and telegraphs, electric lighting, etc.

My staff consists of 18 salaried officers and 80 wages men.

The State is divided into six districts, so far as my work is concerned, and a salaried officer, designated a District Electrical Supervisor, has charge of each district.

The number of maintenance men under each varies, not according to the length of railway lines controlled, but by the amount of apparatus and the miles of telephone and telegraph wire which has to be maintained.

There is a total of 87,205 poles, carrying 17,133 miles of wire.

White ants are plentiful, but I am overcoming this nuisance by supporting all wood work on old rails, wood poles included.

The shade temperature varies from below freezing point up to 112 deg. F., consequently compensation is difficult.

APPENDIX B.

SIGNALLING TRAINS ON THE VICTORIAN RAILWAYS.

Mr. W FORREST (Acting Signal and Telegraph Engineer).

Various methods have been adopted for signalling trains over the Victorian Railways System and range from the simple telegraph with staff and ticket to the modern all-electric automatic signalling.

On country double lines, the block system, employing Winter's block instrument, is used, and, on the single lines, the electric staff system is in operation, using approximately 10,000 staffs. Of the 600 staff instruments in use, approximately 50% are operated by hand generators and the remainder by primary batteries. Special switching-out instruments are installed where it has been found economical to use an intermediate location as a staff station for part-time only. Semi-automatic staff instruments are also in use at certain unattended stations, the instruments being operated by the train crews.

At the larger stations in the country, the points, together with the two-position mechanical signals, are connected to, and operated from, a central interlocking machine, but, at stations where a very small amount of yard work is carried out, the points are either plunger or staff locked, the home signals being operated by quadrants on the station platforms. In all, over 10,000 sets of points on the system are interlocked or otherwise protected.

At several of the smaller stations, which are used for passing long trains, the points are situated at some distance from the stations, and are operated by special levers on the platforms through the agency of a double wire. Points have been operated by these means up to a distance of 800 yards, and have proved very successful in expediting the passing of trains.

Of recent years the efficiency of the train-running has been augmented through the installation of selector telephones at wayside stations. These are connected to a central office and operated by a train despatcher. Over 1,718 miles of country lines are now equipped with these telephones. The system enables the movement of trains over all the busiest sections of lines to be regulated by despatchers located at the main centres, provides greater flexibility of service and enables engines and trucks to be utilised to the best possible advantage. For general intercommunication, about 90,000 poles and 27,000 miles of line wire are in use.

Within the suburban area, an up-to-date system of speed-signalling has been installed. The signals are operated electrically and controlled throughout by track circuits, and, between junctions, operate automatically. They are three-position colour-light and semaphore type and are fully equipped with train stops.

At junctions all points and signals are electrically operated and controlled by interlocking machines with miniature type levers. The interlocking machines are fitted with electric locks and the most up-to-date safeguards, including approach and route locking, are provided. Illuminated diagrams of the junction tracks are fitted over these machines for the benefit of the signalmen. The power for operating the equipment is taken at 2,200 volts from the main power-house and transformed down to 110 volt to operate the motors and signals as required. The cable carrying the 2,200 volt supply, together with all wires controlling the various functions, is carried in wooden trunking built alongside the tracks.

At two of the suburban stations, where the up and down lines terminate at a platform on a single line, the points and signals in and out of the platform are operated automatically by the position of the train on the tracks, the points being reversed for the train from the down road to enter the single line and operating back to normal for the train to depart again on the up line. In the country, there are two junctions where the points and signals are operated by motors using primary batteries, the motors being controlled from the main interlocking machine over two miles away.

Single line automatic signals are installed on a 40-mile section leading to one of the main country towns. The power supply is taken at 6,600 volts and transformed to the standard 110 volts at each signal location. On this section are two unattended passing loops, the points and entering signals of which are operated by the controlling station over three miles away.

Two wires only are used for operating all signals and points at each end of the loops, but complete indication of the position of the points, the location of trains, together with all safeguards in the way of point and approach locking, are provided.

The installation of power operated interlocking machines and automatic signals has resulted in much greater efficiency in train running. The headway of trains and the capacity of the tracks have been greatly increased. Additional safeguards have been provided and, to the train drivers, improved and consistent signal indications are exhibited. Under this system, it has also been possible to abolish certain interlockings which were previously manually operated, and generally safer, more economical and more efficient methods of train signalling have resulted.

APPENDIX C.

NEW SOUTH WALES RAILWAYS—SYDNEY CITY RAILWAY

From the "Australasian Engineer," by the courtesy of the Publishers, and Author, Mr. W. F. BARTON (Signal Engineer).

The Ruling Gradient.

The outstanding feature is that of ruling gradient. From the centre of the bridge to the end of the approach on the North and South sides is 1 in 40 falling and on the South side from the end of approach to Wynyard Station is 1 in 30, one of the steepest gradients on the New South Wales Railways and certainly the steepest in the electrified area. Proceeding towards Central the grade varies, but with a considerable amount of 1 in 30 and 1 in 40, particularly on the low level lines. The gradient diagram for the Down Shore from Central to Argyle is shown in diagram No. 1. Some idea of a 1 in 40 grade can be obtained from the fly-over at Strathfield and hence what is involved in operating on a gradient of 1 in 30 for a distance of three-quarters-of-a-mile.

In order that a driver may receive full "clear" indications—two green lights—it is necessary for the previous train to be a distance ahead equivalent, at least, to three overlaps. Reference to diagram No. 2 explains this.

Allowing for a possible speed of 60 m.p.h. on a 1 in 30 falling grade and a deceleration of 2.2 m.p.h. per second, the overlap required is 2,230-ft., giving a minimum of 6,990-ft. between trains travelling under full "clear" indications. Assuming a service speed of 40 m.p.h. this means a time interval between following trains of 2 minutes, but as a driver travelling at that speed requires considerable sighting time, the signal must clear much earlier in order that the speed may be maintained. In this case, at least 35 seconds would be required, thus giving an interval of 2 minutes 35 seconds between trains. Practical considerations, however, would render such a long sighting-time impossible, with the result that the service speed would be reduced, giving a further increase in train headway. It would be safe to say that a three to four-minute headway would be the maximum possible under such conditions.

Speed Considerations.

The traffic requirements on the section North Sydney-Central demand a two-minutes headway during the rush hours of the day, together with a service speed of 30-40 m.p.h., and the problem at once presents itself as to how this can be effected and maintain an overlap system which meets the requirements for maximum possible speed on a falling grade of 1 in 30. In other words, the block section controlled by each signal must be of sufficient length to provide for maximum possible speed, but for ordinary service conditions, provided the driver is not exceeding the speed requirement, must be reduced in length and therefore in time, the nett result being an earlier clearance of each signal with a consequent increased sighting-time. The driver of a train following closely behind the previous one is thereby encouraged to maintain his schedule speed, but it must be guaranteed that the safe speed is not exceeded. Definite speed values are assigned, therefore, to certain indications and the train stop is not cleared until or unless the requisite speed has been observed.

Simple though this would appear, it means the introduction of several innovations, principally that of a signal displaying a " proceed " indication although the train stop is at stop. Further, an additional indication is necessary so that a driver receives warning of his approach to a section in which the speed is under observation.

The indications employed and the sequence of operations during the passage of a train are as follows :—

The System Explained.

(1) Immediately a train passes a signal the indication displayed is two red lights, indicating " stop " to any following train.

(2) The " stop " indication is retained until the departing train has cleared a point, braking distance for a certain speed explained later, ahead of the next signal, *i.e.*, has cleared the overlap for that speed. At that point the signal shows a small green light beneath the two reds indicating " low-speed." This permits a train to approach and pass the signal at 17 m.p.h. at which speed the train stop clears automatically. Should an approaching train exceed this speed it will be tripped and the brakes applied.

(3) As the departing train proceeds still farther on its way, the signal ahead, in its turn, goes to "low-speed," allowing the signal under observation to display the next higher indication, *viz.*, " caution," or green over red lights. This signal demands an average speed of 30 m.p.h. and the train stop will not clear if this is exceeded.

(4) The next higher indication is " medium," given by green over yellow lights, and is displayed when the signal in advance shows " caution." When the " medium " indication is displayed the train stops at this signal are clear, and the function of the indication is to warn a driver that he is approaching a " controlled area," and so must have the speed of the train in hand.

(5) " Proceed at full-speed," given by two green lights, is the next indication in order and is displayed provided the signal in advance is at a " medium " or higher indication.

These indications and their sequence are shown in diagram No. 3.

It will be understood that the calculations of all overlaps for each signal for each indication entail a large amount of work when it is remembered that the gradient and curvature vary for practically every signal, but for the purposes of this article a few words will suffice to explain the method.

Calculating the Overlaps.

Taking the " low-speed " overlap it has been explained that the train stop at a signal displaying this indication is cleared by an approaching train provided the speed is 17 m.p.h. or less. Therefore, in the calculations of the overlap, 17 m.p.h. was assumed at the signal and from that point a constant acceleration of 1.25 m.p.h. per second on level grade was allowed, correction being made for any other grade. The possible speed attained at the next signal was thus determined. It should be mentioned that over 21 m.p.h. the acceleration is not constant and falls away rapidly. For the calculation of the braking distance, a deceleration rate of 2.2 m.p.h. per second on a level grade was taken, this being equivalent to a retardation value of 10 per cent.

In all overlaps a 30 per cent. margin is allowed over and above the exact braking distance, and this results in the following formula which is derived easily from first principles :—

$$\text{Overlap in feet} = \frac{13\,V^2}{3\,(\%R \pm \%G)}$$

where—V = Speed in m.p.h.
%R = % Retardation.
%G = % grade (e.g., 1 in 100=1%).

For the " caution " overlap a similar procedure was adopted, assuming 30 m.p.h. at the " caution " signal and maximum possible acceleration up to the next signal.

Testing.

Prior to the opening of the City Railway and Sydney Harbour Bridge section each signal overlap was tested for the " low-speed " and " caution " indications and the results obtained were very encouraging from the point of view of accuracy of calculation and the safety obtained.

With regard to the " medium " indication a full-speed overlap is provided on account of the train stop being clear, it being possible for a train to run past this signal and trip at full speed at the " caution " signal. The margin provided is, therefore, sufficient to allow the train to be brought to a stand clear of the train ahead.

On account of the heavy grade and certain considerations determining the spacing of signals it so happens in some cases that the possible speed attainable at a signal, assuming 17 m.p.h. at the signal in the rear, is so high as to render the overlap of prohibitive length. These cases are provided for by installing intermediate train stops between the signals concerned. These stops serve as intermediate checking points for the speed and guarantee that undue acceleration is not made after having passed a " low-speed " or " caution " signal. These train stops only clear provided the signal in the rear has been obeyed as to speed.

The arrangements at platforms call for some further explanation, the station stops always being a source of delay and very often the governing factor in train headway. Obviously any signal, the section for which includes a portion or all of the platform length, has a relatively long clearing time on account of the standing time in the platform and the periods of acceleration and deceleration during starting and stopping. Having the experience of the St. James section for guidance it was decided to eliminate this trouble as far as possible. Four train stops spaced as shown on diagram No. 4 have been installed in all platforms at Town Hall and all but the Down Shore platform at Wynyard. In this latter case the heavy rising grade towards Milson's Point renders it less susceptible to the troubles mentioned.

The provision of the train stops enables the platform entering signal to clear to "low-speed", apparently without overlap, immediately the departing train has cleared the platform. Actually, however, it has sufficient overlap ahead of No. 1 train stop. A following train can pass the in-bound signal at 17 m.p.h. and, provided it does not accelerate, No. 1 train stop will clear. At this point a slight reduction in speed is necessary to clear No. 2 and so on right into the platform, a form of tapered speed control being obtained. This is possible with absolute safety, even though the previous train has come to a stand just clear of the platform.

For ordinary traffic, operating regularly, this arrangement is not actually called upon to function, but should any serious delay occur, e.g., at the dead-end at Wynyard on the low level lines, it would prove most valuable.

In order to enable the elaborate arrangement to serve a definite purpose for fast moving traffic an additional refinement is employed whereby the platform-entering signal is cleared with the departing train approximately half-way out of the platform, provided it has attained such a speed that even though full emergency braking is applied it would be impossible to stop with any portion of the train in the platform.

This enables the entering signal, and all signals in the rear dependent on this signal, to clear anything up to 10 seconds earlier, which represents a considerable saving in dense traffic.

These few remarks cover, briefly, the principles involved in the signalling system and it should be stated that, as a result of the innovations and refinements adopted, and in spite of the exacting conditions imposed, a headway of two minutes at a service speed of approximately 30 m.p.h. can be guaranteed; it follows that, with a lower average speed, a considerable reduction in headway can be obtained. In practice it has been proved that a headway of 90 seconds can be maintained.

The Signal Equipment.

Limited space remains to explain any of the details regarding the actual operating equipment. Electro-pneumatic operation of train stops and point gear is standard on the underground section to Argyle and at North Sydney interlocking; between Argyle and Milson's Point the train stops are all-electric, it being decided not to run an air-pipe line across the Bridge. All other equipment is operated and controlled at 120 volts A.C.

Time element and control relays are of the induction motor type and track relays are the standard double-element type used throughout the electrified area.

Conductor rails or copper feeders have been used in conjunction with one running rail of the track throughout the *underground* section for the traction return current, thus avoiding the use of impedance bonds for double-rail track circuits. *All track* circuits are of the single-rail type, it being possible to show a saving on account of the very short length of each track and hence the large number of impedance bonds required should double-rail track circuits have been used.

The signals are all of the colour light type, those on the underground section being fitted with 5-in. coloured lenses and 4-watt concentrated filament lamps, each individual unit being provided with a transformer. On the open sections the signals are fitted with $8\frac{3}{8}$-in. plain lenses and coloured roundels, each unit being fitted with a transformer and a 36-watt concentrated filament lamp.

APPENDIX D.

TRANS-AUSTRALIAN RAILWAY

(Connecting Port Augusta (South Australia) with Kalgoorlie (Western Australia). Length $1{,}051\frac{1}{2}$ miles).

By the courtesy of Mr. G. A. GAHAN, Commissioner.

Signalling Equipment.

In addition to the usual safe-working appliances met with on railway systems in sparsely populated areas, it has been found necessary to develop and introduce special equipment to meet the requirements of the somewhat peculiar conditions met with on the Trans-Australian Railway.

A brief outline of some of these appliances is given hereunder :

An automatic electric train staff safe-working system is employed. Miniature Webb-Thompson electric staff instruments and 12 magneto-generators are used, and a device, originated and developed in the service, supplied the automatic features.

Under this system, sections up to 86 miles in length are operated, and on the most sparsely populated portion of the railway there is only one attended station for a distance of 340 miles. Metallic line circuits are used so that interferences from earth currents due to electrical storms and other phenomena such as sunspots and aurora displays are entirely eliminated.

Main line currents of 40 milliamperes are used, and all line relays are adjusted and sealed to work on not less than 30 milliamperes. In this way, interference or irregular operation through contact with telegraph wires running parallel with the train-staff circuits is avoided.

A telephone system is superimposed on the electric staff system, and communication is carried through staff block stations by means of repeaters. A portable telephone is carried by every train and rail-car in order that communication can be readily obtained with the depots on either side in cases of breakdowns, emergencies, or for ordinary business purposes.

This telephone system was also developed in the department to meet the altered conditions set up by automatic electric staff working.

Both systems were brought into operation in 1915.

At all unattended staff block stations, and at intermediate sidings, the main line points are locked by electric staff drawer-locks, thus ensuring that these points are normally locked for main line running.

At all unattended block stations, and at intermediate sidings, the main line points are locked by electric staff drawer-locks, thus ensuring that these points are normally locked for main line running.

Another feature is a telegraph circuit of 1051½ miles in length with 15 stations connected without any repeating station.

TABLE 1.

Australia percentage Gauges, 1931	5′ 3″	4′ 8½″	3′ 6″	2′ 6″	2′ 0″
	25·05%	29·01%	45·41%	0.42%	0·11%
	Area in square miles.	Population estimated at 1931.	Route Miles of Railway.	Route Miles per 1000 Population.	Route Miles per 1000 Square Miles.
Queensland	670,500	963,711	6,795	7·08	10·0
New South Wales ...	309,432	2,517,758	6,160	2·46	20·0
Victoria	87,884	1,801,294	4,742	2·64	54·0
South Australia ...	380,070	584,968	3,932	6·74	10·0
West Australia	975,920	421,609	4,911	11·68	5·0
Commonwealth	*524,560	*13,190	*321	*24·4	0·61
Tasmania	26,215	223,390	806	3·68	31·0
Australia	**2,974,581**	**6,525,920**	**27,667**	**4·26**	**9·3**
Great Britain (approx.) ...	**94,633**	**45,000,000**	**20,000**	**0·445**	**244·0**

* *Northern Territory and Federal Capital.*

TABLE 2.

— = Nil

× — Not stated.

	Route Miles of Railway.	Route Miles Single Line.	Ordinary Staff Miles.	Electric Staff Miles.	Telegraph Block and Lock and Block.	Single Line Automatic A.P.B.	Double Line Automatic, D.C.	Double Line Automatic, A.C.	Double Line Automatic, Electro-pneumatic.	Semaphore Arms, Mechanical	Semaphore Arms, Electric.	Semaphore Arms, Electro-pneumatic.	Colour Light Signals.	Shunts and Dwarfs, Mechanical.	Shunts and Dwarfs other than Mechanical.	Signal Reversers.	Train Stop Mechanisms.	Mechanical Signal Boxes.	Power Signal Boxes.	Track Circuits, D.C.	Track Circuits, A.C.	Power-point Layouts, D.C.	Power-point Layouts, A.C.	Power-point Layouts, E.P.
						Mls.	Mls.	Mls.	Mls.															
Queensland ...	6795	6375	6375	400	125	—	12	—	—	3000	30	130	12	×	×	30	—	117	3	100	—	—	—	80
N. South Wales	6160	5495	1256	3176	321	83	251	102	46	3023	853	180	774	1529	851	377	1056	509	19	1754	2548	81	24	456
Victoria ...	4742	4380	1971	2100	229	38	—	70	—	3410	432	—	509	1732	118	680	693	271	8	500	1500	3	232	—
South Australia	3932	2475	—	516	1861	91	53	—	—	320	642	—	64	27	90	77	—	44	2	1042	—	103	—	—
West Australia	4911	4260	3118	1131	63	11½	14½	—	—	1442	20	—	—	×	×	34	—	65	—	90	—	2	—	—
Commonwealth	321																							
Tasmania ...	640	634½	605	30	5½	—	—	—	—	271	—	—	—	—	—	—	—	11	—	—	—	—	—	—

DISCUSSION.

Mr. F. Raynar-Wilson said that the Author was to be heartily congratulated in giving so much information in the space available for the reading of a paper before the Institution. Knowing the formation and size of Australia, combined with the fact that Australian railways had many interesting systems of railway signalling, the information given was very interesting and comprehensive.

He noticed that no mention was made about the railway journey across Australia. The number of times that one had to change trains on account of the break of railway track gauge was a real bug-bear to constant travellers—although somewhat of a novelty to a visitor. When travelling from Perth, the first change was from 3-ft. 6-in. to 4-ft. 8½-in. gauge at Kalgoorlie, on the border of Western Australia. One then continued by the Commonwealth Railways to Port Augusta, where the gauge changed to 3-ft. 6-in. as far as Terowie on the South Australian Railways. Thence to Albury, on the border of Victoria and New South Wales, the gauge was 5-ft. 3-ins. Continuing through New South Wales the gauge was 4-ft. 8½-ins. and, with the new connecting railway, made it possible to enter Brisbane by the same gauge, but previously a change had to be made at Wallangarra when entering the Queensland Railway's gauge of 3-ft. 6-ins.

In addition, one had to change trains at Adelaide, Melbourne and Sydney, so that the journey took six days to complete. On the whole, the travelling was quite comfortable and the rolling stock good.

He thought that the photographs of the Reid's reverser should read as :—1*b* : Lever normal, arm at " danger " ; 1*c* : Lever reversed and arm at " clear " ; 1*a* : Lever reversed but track circuit occupied and arm at " danger." By taking that sequence the operation would more easily be followed. The arm was centre-balanced. When the lever was put back to normal the rod, shown entering the case at the lower right-hand corner, pushed the L lever to a position ready for the next movement.

As a matter of interest, the slide shown of the interior of a signal-box at Sydney was that of Sydney West Box which had 347 levers ; that at Sydney East had 107 levers.

On page 20, the Author mentioned about the signal supply and further particulars were given on page 28. Later, the Speaker hoped to show some slides of the power-station and sub-stations. The railway power-station was situated at Newport, where energy was generated and transformed up to 20,000 volts, 3 phase, 25 cycles, transmitted to the various sub-stations. At the latter, the supply was split up, and one phase was transformed from 440 volts to 2,200 volts for the signal transmission, using either ·015 or ·03 sq. in. copper cable, twin conductor, impregnated paper and insulated lead-covered and wire-armoured mains.

It was mentioned that the A.C.-A.P.B. installation in New Zealand preceded the A.P.B. installation on the Victorian Railways. He did not agree with that statement as far as actual bringing into service, as the Victorian installation was brought into service on December 22nd, 1921, whereas the New Zealand scheme was brought into service sometime in 1922. It was admitted that the New Zealand scheme was sanctioned prior to the Victorian, but the latter was first in operation. The Victorian installation, of approximately 3½ miles length,was on the 2-ft. 6-in. gauge railway, between Upper Fern Tree Gully and Belgrave on the Gembrook line. That line was in the hills and, at holiday time, carried a heavy passenger traffic. A passing station was provided at Upwey, about midway, and provision was made for the train crews to operate the trains in and out of that station. Soda cells, 500 a.h. capacity, were used for signal and track circuit operation. All the apparatus was housed in wooden cases. Copper-weld wires, double-braided and weather-proofed, were run on the telegraph poles. Three wires were used on each side of Upwey station, but eight wires were required for the controls at Upwey. Long-burning oil lamps were used for signals and markers.

No reference was made to an electro-pneumatic installation brought into service on the Queensland Railways at Mayne in 1928. Here a 120-lever frame was installed.

On page 28, mention was made of two junctions where points and signals were operated by primary batteries. On one installation—at Castlemaine—primary batteries were used, but at the other there were trickle-charged accumulators. The latter installation was opened on August 16th, 1925, and was on the main Melbourne-Sydney line between Seymour and Tallarook, a distance of 5½ miles. The main line was single-track for two miles out of Seymour, owing to there being a single-track bridge over the River Gouldburn. That bridge was built in the early days of railway construction and the cost to duplicate it was very high. In order to allow more intensive traffic operation, the points at the junction of double to single track were operated from Seymour and suitable signalling provided. Electrical supply was obtained from Seymour at 230 volts, 50 cycles, single phase and was used for trickle-charging the accumulators. Several types of rectifiers were used. The wires were carried in wooden trunking to past the junction and thence on telegraph poles.

A few further particulars might be added concerning the 38 mile installation of signalling between Newport South and Geelong ,Victoria. Power was obtained from Newport sub-station at 6,600 volts, 25 cycles, single phase and transmitted by two 7/·064 bare copper conductors, transposed each mile. These conductors were spaced 6-ft. 6-ins. from the other wires on the telegraph poles. That installation was opened in August, 1928, and was signalled for an 11-minute headway.

(Some lantern slides were then shown and described by Mr. Raynar-Wilson).

Mr. J. C. Kubale said he would like to extend his appreciation to the Author for his very interesting Paper and to Mr. Raynar-Wilson for his additional explanation of the signalling on the Victorian Railways. He, also, was more acquainted with the Victorian Railway signalling than that of the other States and he hoped that their New South Wales friends would not misunderstand the coincidence of two successive speakers referring particularly to the same railway. The following was a brief outline of the development of signalling on the Victorian Railways :—The first railway was opened on September 13th, 1854, and was a two-mile line from Flinders Street, Melbourne, to Port Melbourne–then called Sandridge. That was the first of a number of privately-owned lines but by 1878 practically all the private companies were absorbed into a National system, out of which had grown the present system, known as the Victorian Government Railways. The first interlocking frame on the Victorian Railways was installed in 1876, the block telegraph in 1880, the needle block instrument in 1883, the electric tablet instruments in 1892, lock-and-block instruments in 1896, track circuit control of signals in 1897, electric staff instruments in 1897 and three-position signalling in 1915.

In Melbourne and Sydney much of the new signalling had developed mainly as a result of the electrification of suburban lines which had been carried out in those cities. Flinders Street Station, Melbourne, had remained the busiest centre for suburban passenger working and the traffic movements of that station were very interesting. The majority of the sixteen platforms were through platforms. The total length of those sixteen platforms amounted to about $1\frac{3}{4}$ miles. Approximately 2,566 electric and 168 steam trains passed through or left that station each day. According to statistics for a period in 1927 the daily average number of passengers passing through the barriers was 317,393.

The Signal Engineers in Australia were more or less isolated and probably found it difficult to keep in touch with new developments in Europe and North America. Also, and because they were so far away from the works of signal manufacturers, they found it necessary to maintain fairly complete workshops in which to manufacture certain of their own requirements and to carry out the necessary repairs. In spite, however, of this apparent isolation, he thought it would be agreed that the Signal Engineers in Australia had accomplished a great deal and were keeping well abreast of the times, as evidenced by the matter which had been presented in the present excellent Paper.

Mr. H. E. Morgan remarked that, interesting as the Paper had been, its value had been enhanced by the additional information which had been given by Mr. Wilson and the slides which he had exhibited. Very few people realised the size of Australia and it was a very surprising comparison to see the map of Australia superimposed on that of Europe.

Conditions out there appeared to be very mixed. For instance, there was a great difference in traffic conditions in various parts; the service of trains varied from 30 per hour to one per day, whilst the temperature variations covered a wide range from 112 deg. Fah. to below Zero.

The signalling arrangements, generally, seemed to vary from the simplest form to that of the very latest ideas. Australian signalling practice covered some very unique arrangements; for instance, the upper quadrant two-position signal exhibited three aspects by day, but only two by night. The arrangement for d.c. apparatus being operated through rectifiers, with a stand-by primary battery in the same circuit, was another innovation, which, to his mind, had not been tried in this country.

He agreed that the reverser fulfilled a very useful purpose, especially in connection with track circuits. He always contended that it was very little use locking a signal unless precautions were taken to see that the signal was placed at " danger " behind each train, in order to obtain the security of the track circuit locking. That could only be effectively done by either the provision of a reverser to automatically restore the arm to " danger," or by providing, as is sometimes done in this country, rotation locking to ensure the lever being placed normal after every train. He was familiar with the type illustrated on the screen. It was called the Reid type, and was tried some years ago on the Midland Railway.

Reviewing the signalling in Australia as a whole, he thought it would be agreed that they had almost a little bit of everything and he was sure that the Institution was very much indebted to the Author for the valuable information contained in the Paper.

Mr. G. H. Crook said that Mr. F. Raynar-Wilson had rather taken the wind out of his sails by his interesting remarks and the exhibition of the fine views he had shown on the screen. The Speaker, however, took this immediate opportunity of thanking the Author for his splendid paper, which was a descriptive, informative and extremely interesting resumé of Australian signalling. It was a valuable paper and the Institution was fortunate in having made so accessible some of the facts of the work and upon which their Australian brethren might be congratulated.

He had not had the time to study the paper as it deserved. However, dealing with geological characteristics in which it was suggested that Australia might be younger than other parts of the world, he had turned up a geological report dealing with the Mt. Buffalo ranges mentioned in the paper which are approximately 5,000 feet high. The Geologist suggests, from the evidence of the granite crown, that these were originally covered with sedimentary rock to a height of 15,000 or more feet and therefore in the course of ages a covering seam, perhaps two miles deep, of soft rock had been washed away. That, of course, must have taken a very long time !

The Author also mentioned coal not having had time to turn black. There was a huge power-generating station at Morwell, known as Morwell Brown Coal Mine. The thermal efficiency of the brown coal was such that about 2¼ tons of it were only equal to 1 ton of black coal.

The Paper mentioned, as regards the difference in climates, that winter sports were indulged in at Mt. Koscinsko and Mt. Buffalo. The former rises to 7,336 feet and the latter to 5,645 feet, and there are several peaks in the mountain ranges above the 6,000 feet line which were completely snowed up in winter, affording Alpine conditions. Personally he had enjoyed better skating in Australia than in Southern England.

With regard to the reversers; these appeared to be favoured rather than electric locks. They were possibly more difficult to operate and more expensive than electric locks, which was the reason for the different British practice. The reverser, however, made the signal control automatic which was an advantage they should keep in mind.

The spark-gap earthing device was an ingenious arrangement. Before that device was designed an experiment was made of connecting the overhead traction structures direct to one rail of the track circuit which was equipped with impedance bonds, but the unbalancing effect was so considerable as to completely upset the proper operation of the track circuit. The Traction Engineer required earthing protection and so the spark-gap device was designed. The insulation consisted of a fine layer of paper about the thickness of cigarette paper.

The electro-mechanical frame was a neat combination, particularly suitable where the bulk of traffic was of a through nature. Where point movements were, however, very frequent it would, he thought, tend to slow down the speed of operation. Possibly that was hardly a proper time for such comparisons, but, in suitable applications, electro-mechanical frames had been used very satisfactorily.

Reference was made to private railways of which there was only a very small mileage in Victoria. He had had the pleasure of travelling on one of these so-called private railways—the Powell Town Tramway—the locomotive was then burning wood fuel and made a spectacular display of sparks, reminiscent of a fireworks display.

In general, he thought most people would agree with the last two paragraphs of the paper which dealt with trading difficulties. The question of tariffs was, of course, a very touchy one, and possibly that would ultimately be solved by the politicians who had not yet "matured." Personally he thought that if tariffs became prohibitive, they must recoil like the boomerang.

They had seen some very good comparisons of the magnitude of Australia on the screen. One point he might mention was that it took the Sun more than two hours to pass over Australia with the result there were three different times. The Sun rose in the East and set in the West but its transit was *via.* the North, a point to keep in mind if one were " bushed " and without a compass !

Mr. Raynar-Wilson had stressed the difficulty of the various railway gauges in doing the Trans-Australian journey. That was a matter which was periodically inquired into by a Commission, but each estimate produced was higher than the previous one, and it was difficult to say whether the gauge problem would ever be solved.

There was one rather singular installation which the Author had not mentioned and that was the electric-tramway crossings at Melbourne where there were overhead railway traction wires.

Here, a small isolated section of overhead wiring was made common to either railway or tramway and was energised at 1,500 volts for the railway and 600 volts for the tramway, the correct voltage being controlled by the position of the level crossing gates. The return rails were isolated and similarly connected to either railway or tramway systems as required. The crossing section was also track circuited so that, in the event of an over-run on the railway, the tramway circuit breakers were tripped out. The tramway was protected by derails and road signals. The track circuiting of the level crossing presented a peculiar problem, as occasional contacts across the insulating tramway joints occurred, allowing a D.C. flow of anything up to 800 amps. from railway to tramway system. That condition was met by utilising the two sections of an ordinary impedance bond as an isolating transformer for the track relay. Contactor switches for connecting the level crossing rails with either railway or tramway system were designed, manufactured and installed by the Victorian Railways Signal Engineer.

It would perhaps be a little ungenerous to say anything about the braking formula appearing on page 32. Personally he thought it preferable to allow for a percentage of safety on the retardation factor only, instead of applying the percentage to the total expression. The per cent. " G " was a function directly dependent upon gravity and was not subject to the same variation as per cent. " R ". Also he did not think they could speak in terms of an exact braking distance, and all that could be ascertained was the average of a series of results and then perhaps allow a certain reasonable margin of safety above that average. The point raised was possibly of theoretical rather than practical importance. There was, of course, nothing exclusively Australian about that formula which, in different ways, probably had world-wide application. It was used by Capt. Galton at the Institution of Mechanical Engineers in 1879.

The single line staff section of 86 miles in length on the Trans-Australian Railway was very interesting and was probably a record length. Apropos of that railway, which perhaps at one time had not the best record for punctuality, the Speaker recalled a story which was regaled in Australia some years ago. The Trans-Australian express from Port Augusta to Kalgoorlie, alleged to have been habitually running late, was, on one occasion, reported up to time and arrangements were made at Kalgoorlie for the Mayor and a band to meet the train on arrival. The driver was duly congratulated but stated that his was yesterday's train! It is, of course, a fact that such a railway was only worked under extremely difficult conditions.

In conclusion, the Speaker thought that both Australia and the Australians were to be congratulated on the advances made in railway signalling in a relatively short space of time.

Mr. A. W. Woodbridge said he would like to be associated with the previous speakers and join in congratulating the Author on his Paper. He had had a number of interesting talks with that gentleman before he returned to Australia, and also with Mr. Crook and Mr. Kubale, all of whom had had experience of railway working in Australia.

He noticed that the Australian Railways had always used signal replacers instead of electric lever locks and were also going in for C.T.C. systems. In other words they had the "locking" outside the signal-box instead of inside which should be the proper place for any locking or its equivalent.

Some months ago he was shown some interesting diagrams of the installation on the Geelong Railway. The control was done by using half-wave rectifiers and the positive and negative half of the alternating current waves. The ordinary commercial 50 cycle alternating current was used instead of any specially timed impulses. By this means both ends of a passing loop and the appropriate signals were controlled over one wire. Indications of the position of points and signals and also of condition of track circuits were also given over the same wire. He understood that the Signal Department staff were responsible for the design of the whole system.

Another point struck him in regard to the photographs shown. He noticed that the Melbourne Railways were using large overhead gantry structures for the traction system. He would like to know what the Locomotive Department had to say about this from the point of view of sighting signals.

With regard to speed signals on gantries, they have three signals one above the other, the top signal must have been about 40 feet in height. In this country they were grumbled at if they went above 20 feet! Had the locomotive drivers any difficulty in sighting such signals?

One thing he was thankful for and that was that in this country they were not troubled with white ants. He thought the trouble caused by rats was quite sufficient to cope with. He would like to congratulate the Australians; they seemed more go-ahead than any other Overseas British Possession, except perhaps Canada.

The **President** said that, thanks to those who had been in Australia, they had had a most interesting discussion and he would like to thank the Author for his very interesting Paper.

With regard to the question of the reverser some people thought it better to "prove" the lever. He did not know that it mattered much as long as the arm was at "danger" before another train was accepted up to it.

Mention was made in the Paper of all-electric frames. Did he understand that to be electric interlocking in addition to the electrical operation of the signals and points?

Mr. Barton of New South Wales made a point that on the New South Wales Railways there were always two stop signals at "danger" behind the train. He did not know why.

He congratulated the Australians in using up their old frames.

Mr. Raynar-Wilson, in his slides, showed some overhead wires going across to the signal. He would like to know whether they were insulated or bare wires.

He would ask them to join with him in passing a very hearty vote of thanks to the Author for his very interesting Paper and to Mr. Tweedie for the very able way he had read it.

The Author (communicated): I thank the President and the other speakers for the cordial reception they accorded the Paper.

Mr. Raynar-Wilson's description of the R reverser illustrations is quite correct. It is a matter of taste what part of the cycle of operations is shown in the first picture. As shown it draws attention to the fact that after the train has passed–and without action on the part of the signalman—the arm is put to " stop ". Also, that the signalman must put his lever normal before he can clear the signal a second time. Both are valuable features.

I believe Mr. Wilson's dates for the A.P.B. installations are correct. Three power signal-boxes are listed under Queensland in Table 2. These are Brisbane Central, Mayne and Gympie.

Referring to Mr. Crook's remarks. The youth or age of a country are purely relative so we will not argue about it.

I thank him for describing the tramway crossing arrangement, which was an interesting development.

I am inclined to agree that the term " Exact braking distance " in App. C. might be misunderstood" -Calculated" might be better.

The " R " used and obtained from tests is an over-all figure and actually varies slightly for the same train depending on the speed at which the brakes are applied. An equipment which will stop from 30 m.p.h. in a distance equivalent to R=10% will probably show R=9% from 60 m.p.h.

I note his point about the formula but at the same time it is common practice to add the factor of safety to the finished calculation and the N.S.W. formulae does this.

I think Mr. Crook's humorous story about the Trans-Continental train a good one. It must be remembered that this line runs a very fine service under difficult conditions.

I remember an occasion when the trains in both directions were delayed by a water truck becoming derailed at a crossover. Although the difficulty was handled most expeditiously, both trains ran out of soft drinks before we got away ! ! ! The increase in temperature due to the stoppage of the train was remarkable although all fans were kept going.

Some members may not be aware that this train has a drawing room with a piano, a card room, dining saloon and shower baths, etc., and passengers are provided with a paper bag to protect their hats from the fine dust. The scenery on the route is distinctly monotonous.

The circuits developed by the Victorian Railways' officers and referred to by Mr. Woodbridge are very ingenious and are, I understand, giving satisfactory results.

The sighting of signals on the Victorian Railways was carried out very carefully and the Locomotive Department was represented on the Sighting Committee. The proportion of multiple-track road is not great and the signals are much lower on double track as illustrated in the slides, etc.

Referring to the remarks of the President, the term " all electric frame " as used includes mechanical locking between levers. One locally renovated miniature lever locking frame *without* mechanical locking is in use on N.S.W. Railways at Epping. The latest installation, which is at Caulfield in Victoria, retains mechanical locking.

The general practice is to use double braided weatherproofed line wire from pole line to signal or relay box pole.

Two red signals occur behind a train where the length of block is less than the braking distance. N.S.W. suburban trains have a free running speed of 55 to 60 miles per hour.

I wish that the other Australian Railways had been represented in the audience and also that more home members had taken part in the discussion. I thank Mr. Morgan and Mr. Kubale for their comments, which do not call for reply. I also thank Mr. Tweedie for reading the paper and for making the other necessary arrangements.

Proceedings 1934.
Part I.
Inset Sheet No. 1.

RAILWAY SIGNALLING IN AUSTRALIA (*Prescott*).

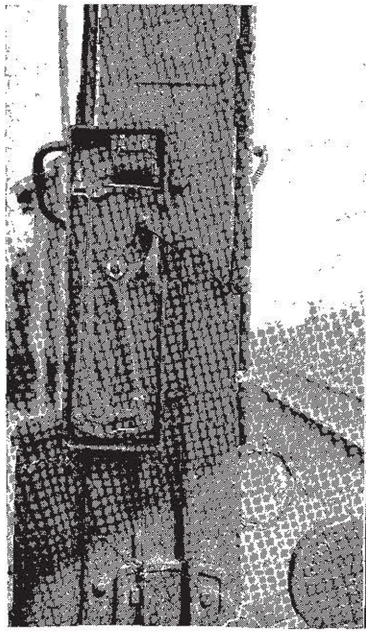
Fig. 1a.

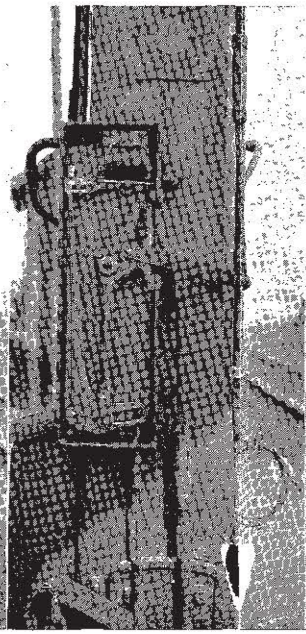
Fig. 1b.

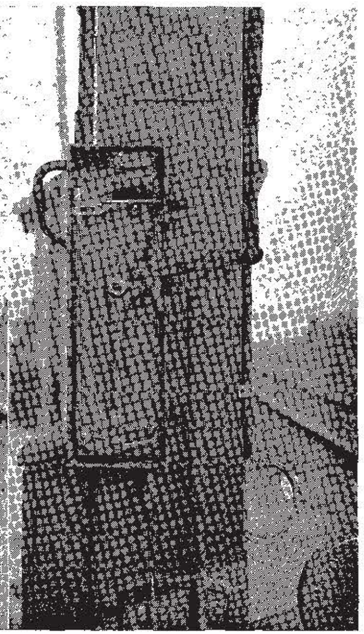
Fig. 1c.

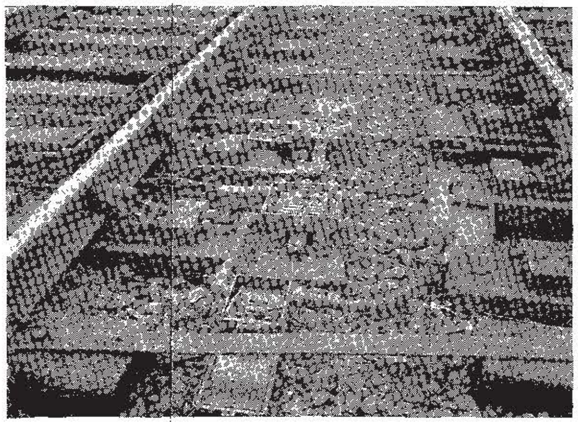
Fig. 4.

RAILWAY SIGNALLING IN AUSTRALIA *(Prescott)*

Appendix C.

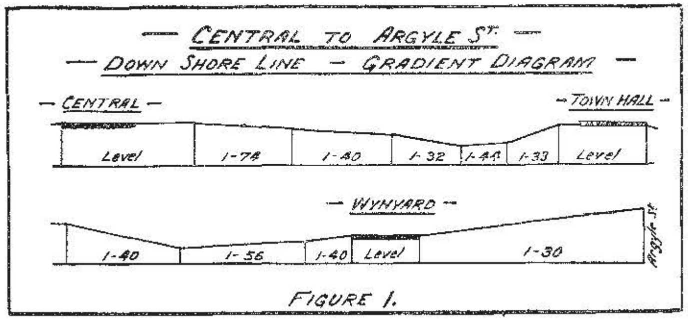

FIGURE 1.

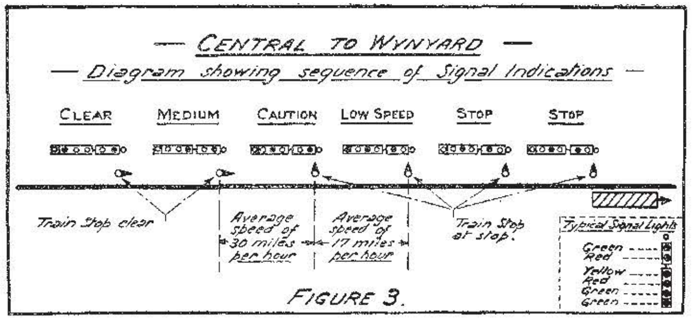

FIGURE 3.

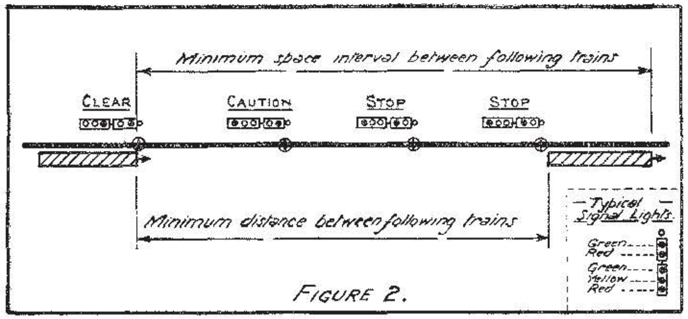

FIGURE 2.

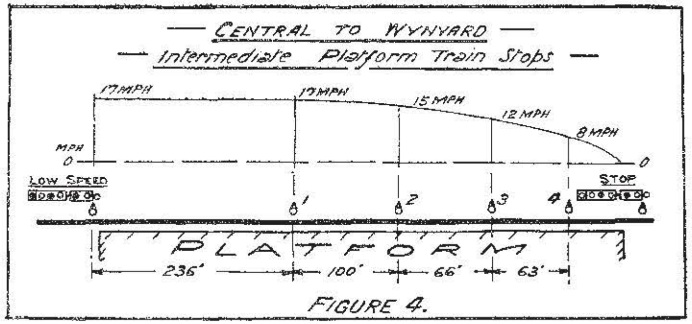

FIGURE 4.

MODERN AUTOMATIC SIGNALLING, SYDNEY CITY RAILWAY.

The above figures which must be studied in conjunction with the article on the signal control of the Sydney City Railway, specially prepared by Mr. W. F. Barton, Chief Signal Engineer to the Railways, illustrate very clearly the manner in which the system operates. With modern automatic signalling such as this is, a great deal depends on timing, consequently, increased and decreased speed resulting from changes in the grades of the lines, all play their part in designing such a system.