Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Tuesday, January 12th, 1954

The President (Mr. T. AUSTIN) in the chair

After the minutes of the Technical Meeting held on December 17th, 1953, had been read and confirmed, Mr. R. L. Cant, Mr. N. W. Bernard and Mr. E. J. Harris, present for the first time since their election to membership, were introduced to the meeting.

The **President,** in extending a hearty welcome to those present said that he was sure they would be very interested in the paper, and he hoped that many would join in the discussion to follow. He then called upon Mr. J. P. Loosemore to read his paper on " Level Crossing Protection."

Level Crossing Protection

By JACK P. LOOSEMORE (Member)

Diagrams—Inset Sheets Nos. 1-8

Introduction

Road users in the United Kingdom know from experience, the feeling of utter frustration that descends upon them whilst they are kept waiting at a railway level crossing for what seems inevitably to be, the goods train which will sooner or later puff into view and pass slowly over the railway in front of them. Even after the train has cleared the intersection, a lengthy period seems to elapse before the crossing keeper sees fit to open the gates to permit the road users to continue their journey without further hindrance. In their impatience, the road users overlook the fact that the arrangements provided at level crossings are designed primarily for their protection and that the delays which they encounter, inconvenient though they might appear at the time, are considered essential to their own well-being.

In some instances, of course, the road users have a legitimate grievance. One such occasion occurred some months ago when a train from Lincoln to Derby stopped on the crossing at the Nottinghamshire village of Lowdham and stayed there for forty minutes on a busy Saturday afternoon whilst the driver and fireman had an argument as to whether the train should proceed or not. Happily, such lengthy delays are most unusual ; it must be admitted, however, that at times even the normal period during which road traffic is kept at a standstill at level crossings, appears excessive.

Nevertheless, whether the delay be short or long, let one accident occur at a level crossing and a public outcry invariably ensues. The matter thereafter becomes sometimes one of local importance and sometimes one of National interest. From the unfavourable criticisms then levelled in the Press and more often than not the questions that are subsequently raised in the House of Commons, it is evident that the general public is of the opinion that the safety devices provided and the precautions taken at level crossings, leave some room for improvement. This, despite the fact that the number of accidents which occur annually at such locations and the casualties incurred thereby, are insignificant when compared with those experienced daily on the roads.

The need for providing adequate protection to safeguard the movement of rail and road traffic over level crossings has of course, existed since railways first came into being. Except insofar as a few details and particular layouts are concerned, the design of the crossing equipment installed in the United Kingdom is substantially the same as it was 100 years ago. In other countries, however, the design of the safety devices for use at such locations has undergone considerable changes over that period of time.

The primary object of this paper is to analyse the level crossing arrangements at present obtaining in the United Kingdom with the view to considering whether any benefits can be derived by the adoption of some of the features of the arrangements employed elsewhere. To this end, the paper has been subdivided into three parts, viz :—

Part I Level crossing arrangements in the United Kingdom.

Part II Level crossing arrangements outside the United Kingdom.

Part III Possible improvements to United Kingdom practice.

Part I

LEVEL CROSSING ARRANGEMENTS IN THE UNITED KINGDOM

Types of Crossings

In the United Kingdom, the level crossings can be classified roughly under three headings as follows :—

(i) *Public Road Crossings*

These number approximately 4,450, some 4,080 of which are equipped with manually attended gates.

(ii) *Private Accommodation or Occupation Crossings*

Of these there are a total of approximately 22,600. By far the greater proportion of them are of the field-to-field or " accommodation " type. The next in order of magnitude are the farm or private estate to public road or " occupation " type. At such locations unattended gates are provided.

(iii) *Footpath Crossings*

No statistics are available to show how many of these are in existence.

Ministry of Transport Requirements

The protective arrangements to be provided at the various types of crossings are prescribed by the Ministry of Transport under Clauses 57-60 inclusive of the publication issued by them entitled " Requirements for Passenger Lines and Recommendations for Goods Lines."

Although the design of signalling apparatus in general has been changed and has been improved, sometimes beyond all recognition since the railways were first constructed, it is surprising to find as mentioned earlier, that the same cannot be said about the equipment installed at level crossings throughout the United Kingdom. The road surfaces over such crossings undoubtedly have been improved in recent years to such an extent that they are in fact in most instances, level in the true sense of the word. The manner in which traffic movements are protected and the appliances that are used in conjunction with such arrangements are however, virtually the same as those employed when the problem first arose.

This state of affairs should not be regarded as a reflection on the ability of the Signal Engineers of this country to move with the times nor should it be taken as an indication that those gentlemen are satisfied that the British practice in respect to level crossing protection cannot be improved upon. Their hands are tied in this matter by virtue of the fact that the protective arrangements to be provided are governed by the following laws :—

(i) *The Level Crossings Act of* 1839.

(ii) *The Railway Regulation Act of* 1842.

(iii) *The Railways Clauses Consolidation Act* (*Paragraph* 47) *of* 1845.

(iv) *The Railway Clauses Act* (*Paragraphs* 6 & 7) *of* 1863.

(v) *The Light Railways Act* (*Paragraphs* 24 & 25) *of* 1896.

Those laws are still in force today ; the Ministry of Transport's Requirements and Recommendations merely amplify the legal essentials. Legislation would therefore have to be introduced in order to enable the Signal Engineers of the British Railways to abandon the old methods and to supersede them by the more modern contrivances that are now available.

Railways' Concern

There can be no doubt that the railways themselves regard level crossings with disfavour since they are responsible for the erection and maintenance of the protective equipment and bear the full costs incurred thereby. They must certainly be very apprehensive too as to the suitability of the existing protection arrangements at some of the crossings. With the increased weight, speed and density of the traffic now prevailing on the roads and particularly the heavier tractors and appliances used on farms, the very real possibility exists of a train coming into collision with a vehicle on a crossing and being derailed. At one time, the train could have been expected to hold its own in such an eventuality ; the risk today however, is very great as a serious accident involving heavy casualties to the railway travellers, could occur despite the comprehensive and sometimes elaborate precautions taken by Signal Engineers to safeguard the passage of trains over other parts of the railway system. Providentally to date, the number of railway passengers killed as a result of level crossing accidents has been negligible ; nevertheless, the potential danger should not be overlooked.

Level Crossing Accidents

It is unquestionably a fact that in the majority of cases, accidents at level crossings are caused by the foolhardy and negligent behaviour of the road users themselves or by a mistake on the part of the personnel responsible for the opening and closing of the gates. In very few instances is the equipment found to be at fault.

In order to view the position in its correct perspective and to appreciate the effectiveness of the safeguards provided, it is necessary to study the statistics in regard to accidents that occurred at level crossings in the United Kingdom during the years 1947-1951 inclusive. The figures given below have been extracted from the Annual Reports of the Chief Inspecting Officer for Railways to the Minister of Transport in regard to Accidents on the Railways of Great Britain.

			Public Road Crossings						Occupation Crossings			Footpath Crossings		
			Gated			Ungated								
			4080			370			22600			Unknown		
Year	Total Number of Accidents	Total Number Involving Casualties	Number of Accidents	Persons Killed	Persons Injured	Number of Accidents	Persons Killed	Persons Injured	Number of Accidents	Persons Killed	Persons Injured	Number of Accidents	Persons Killed	Persons Injured
1947	247	60	163	20	42	2	–	2	68	8	15	14	12	3
1948	251	70	175	20	11	5	–	5	65	25	2	6	6	–
1949	200	68	147	23	13	5	1	5	42	13	22	6	5	1
1950	235	65	151	13	12	10	1	7	66	15	33	8	6	2
1951	208	60	127	4	15	11	2	8	68	14	27	2	2	–

Analysing these figures it will be seen that during the five years under review :—

(i) The total number of persons killed was 190 (average 38 per annum).

(ii) The total number of persons injured was 225 (average 45 per annum).

During the same period the accidents reported on the roads in the United Kingdom resulted in 24,429 persons killed (average 4,886 per annum) and 889,764 persons injured (average 177,953 per annum). The level crossings therefore compare very favourably.

At this stage it may possibly be worth while to examine the arrangements at present obtaining in regard to crossings in the United Kingdom.

Public Road Crossing Arrangements

At all public road crossings, the railways are legally obliged to provide and maintain suitable protective arrangements to enable the public to use the crossings in safety.

Except in comparatively few instances, generally where light railways only are concerned, gates are provided at all such locations.

The gates are usually designed somewhat on the lines shown in fig. 1 and are of substantial wooden construction, the lower portion of each sometimes being covered with large mesh wire netting or expanded metal. They are painted white and sometimes carry a red target approximately 3-ft. in diameter and a red lamp. The targets and lamps are arranged to show in both directions along the railway and along the roadway according to the position of the gates ; it is not essential however, for them to be displayed to the railway if there are " stop " signals protecting the crossing. On skew crossings the lamps, if required to show in both directions, are fitted with mechanical revolving gear actuated by the movement of the gates which automatically faces them in the right direction. The targets and lamps are a comparatively new requirement, since they would appear to have been first called for by the Ministry of Transport in 1925. It would seem that the railways are under no legal obligation to provide them on crossings over railways constructed before that date, which probably explains why they are not found at all level crossings. In their absence some Regions, if there is a street lamp in the proximity of the crossing, arrange with the local authorities for the lamp glass facing the oncoming road traffic to be coloured red.

At crossings over very busy roads, red reflectors are sometimes fitted on to the gates to enable them to be picked out by motor car headlights; it is usually left to the Highway Authorities to supply and fix these however, at locations where they consider them to be desirable.

The gates are hung on square shafts supported in footstep and top metal bearings (in some cases adjustable) fixed to heavy posts sunk into the ground. Provision is made for adjusting and raking the weight of long gates by means of diagonal tie rods and adjusting screws. For movements of up to 90° an adjustable half crank is usually fitted on to the square gate shaft, to which the gate operating rod is connected below the road level. If a movement of over 90° is required, a rack and pinion device is employed in lieu of the half crank ; such an arrangement is in fact preferred by some engineers for all gates irrespective of the angular motion.

As a general rule the gates are kept normally closed across the roadway and open inwards towards the railway. In special cases however, permission is granted by the Ministry of Transport for the normal position of the gates to be across the railway. Whichever arrangement is adopted, the gates have to be worked either from a signal box or by an attendant, unless they are normally across the railway and authority has been obtained for them to be opened and closed by trainmen.

Except in special circumstances, the gates are interlocked with the signals ; at busy crossings " stop " as well as " distant " signals are provided, whilst at the lesser important ones worked " distant " signals are sometimes considered adequate. Fixed " distant " signals are only permitted for those crossings at which the gates are worked by trainmen, but even so, the Ministry of Transport prefer suitable distant warning notices, illuminated at night for such locations.

When worked from a signal box or gatekeeper's lodge by means of rodding, it is customary to open and close the four gates for a crossing simultaneously. The manner in which the connections are made varies according to the preference of the Region concerned, but the arrangements depicted in fig. 2 will serve to illustrate the principles involved. In instances where the width of the line exceeds that of the roadway, special methods have to be adopted and it is then usually arranged for the gates to overlap when closed against the road traffic ; the reverse of course, also applies. This is generally achieved by operating two of the gates in advance of the other two, either by having a separate drive for each pair of gates or by incorporating suitable escapement gear in the connections.

$1\frac{1}{4}$-in. diameter solid rodding or $1\frac{1}{2}$-in. bore piping is usually employed for the gate operating connections. As the rodding has to be run below road level, it is necessary for it to be protected by some means. The general practice is to lay the runs in concrete troughing covered either by concrete slabs or by metal plates. An alternative method is to run the rodding in an oil filled pipe equipped with stuffing boxes and glands at each end, the pipe and rodding being buried direct in the ground. With such an arrangement the rodding being oil immersed, requires no maintenance and functions very freely.

Although gate rodding is more substantial than that used for point operation, it is still not rigid enough to hold the gates firmly in position when opened or closed. This is probably due to the fact that the gates are worked from the hinges and that consequently because of leverage, they are easier to move from the toes. For this reason stops are provided to secure each pair of gates. Each stop comprises a back member which is used as a buffer to prevent the gates being carried too far by their own momentum, and a front member, the purpose of which is to lock the gates against the back member. Means have to be provided to prevent the road stops rising to form an obstruction which could cause injury to the road users, and for this reason it is usually arranged for them to remain down until the gates are almost closed.

At one time it was fashionable to use what are known as detector stops, these being designed to detect mechanically the presence of the gates before permitting the lock lever to be put normal to free the signals. These would appear to have gone out of favour for general use but they are however, still employed for power operated gate schemes since they can be used to cut off the supply to the gate mechanisms at the appropriate time.

A total of four stops are used for each crossing, two in the roadway and two in the railway on each side of the crossing. As a general rule all four stops are worked from one lever, the two road stops being raised when the two rail stops are lowered and vice versa.

For rod worked gates that are operated mechanically, two types of gate wheels are in common use. One is of the capstan type which comprises a set of toothed gear wheels engaging with a rack quadrant attached to a vertical crank. The other is of the horizontal screw type in which the wheel is attached to a screwed shaft on to which is threaded a nut which is provided with trunnions to engage with a fork in the end of a vertical crank. With both types the rodding is taken off from the vertical crank. The gate wheels are mechanically interlocked with the gate stop lever and in general practice are fixed at the end of the frame nearest the crossing to enable the signalman to observe the road traffic.

To open the gates, the stop lever is moved to its first notch ; this action lowers the road stops and allows the rail stops to rise in readiness to receive the gates. The gate wheel then becomes free and the gates can therefore be moved into position across the railway. When the gates are fully opened, the stop lever is moved fully to its reverse position, thus locking the rail stops and back locking the gate wheel. A similar sequence of movements is followed for closing the gates, except that the road stops will not rise until the gates are nearly home.

For gates at very busy crossings, power operation is sometimes employed. To obtain satisfactory results, it is necessary for the operator to have full control during the whole time in which the gates are in motion in order to allow for the varying conditions, such as the inertia of the gates, windage, etc. If not properly controlled, the gates with a high wind will slam in one direction and will not close properly in the other. Remote control is not advocated.

Electric oil gate machines have been used at a number of crossings with successful results. They provide flexibility of speed control without elaborate electrical gear and are designed to enable the motion of the gates to be reversed at any time should an obstruction be encountered. Gates have also been worked satisfactorily at some locations by all-electric, all-pneumatic and electro-pneumatic means.

Where gates are opened and closed by hand, they have to be secured by a latch or some other means and arrangements must then be provided to prevent the latch being dropped in until the gates are actually in position. The controlling lever is then placed normal which back locks the latch, an electric lever lock and controller generally being used for this purpose.

Wicket gates are provided for pedestrians unless an over-bridge or under-bridge exists. These are usually of the self-closing type and locked from the signal box by means of chain or slotted link.

A separate lever is generally employed for each gate to eliminate the possibility of pedestrians being locked in the crossing.

In electrified areas, where third rail and fourth rail traction systems are employed, it is of course, necessary for the traction current rails to be cut back clear of a level crossing to prevent injury to road users. Where an overhead traction system is used, it may sometimes be desirable to erect danger notices across the roadway to show the headroom clearance afforded by the catenary wires.

Where an attendant is placed in charge of a crossing between block posts, a block repeater is usually provided in the gate-keeper's lodge. This sometimes merely takes the form of a bell placed in parallel with the block circuits thus enabling the attendant to hear all codes which are exchanged between the adjacent signal boxes so that he can be prepared for approaching trains. Visual indicators are preferred however, in order to preclude the possibility of the attendant misunderstanding the codes transmitted. In any case, at such locations British Railways Rule No. 100 requires the attendant to satisfy himself that no train is approaching before placing his rail signals to " caution " or " danger." Approach locking is seldom if ever, employed to prevent the replacement of the " distant " signal after a train has come within sight of it or has passed it. In addition, British Railways Rule No. 106 stipulates that the attendant must satisfy himself that his signals are working properly. If they are out of sight, arm and light indicators are therefore usually provided in the gatekeeper's lodge but indication locking is never used.

At crossings carrying dense road traffic, traffic light signals of the conventional pattern are sometimes installed to give warning to road users that the gates are about to be closed. These are provided by the railways in conjunction with the Highway Authorities and are of course, a comparatively recent innovation. Fig. 3 gives a typical circuit arrangement. From this it will be seen that assuming the gates are closed across the roadway and it is wished to open them, the initial movement of the gate stop lever to its reverse check lock or " D " position will cause an amber-red aspect to be displayed in the traffic signals, and will free the gate operating gear. This condition will be maintained until the gates are fully opened and the gate stop lever has been moved to its full reverse or " R " position, whereupon the amber/red aspect will be replaced by a green one. To close the gates once more, the gate stop lever must first be moved to its reverse lock or " E " position ; this will result in the de-energisation of the " DR " and will cause an amber aspect to be displayed in the traffic signals, but the gate operating gear will still be locked. After a predetermined time (usually 3-4 seconds) the "JR " will become de-energised and the light signals will display red aspects. When this condition has been proved, the gate stop lever can be moved to its normal check lock or " B " position to free the gate operating gear. With the gates fully closed, the gate stop lever can be restored to its full normal or " N " position to free the rail signals, the road signals being maintained at red.

It is understood that in practice motorists and cyclists often try to beat the lights when the gates are being opened. This is no doubt, because of the length of time during which the amber-red aspect is displayed.

A very important adjunct to level crossing protection arrangements is the provision and correct positioning of advance warning signs on the railway and on the roadway to ensure that the users of both will have prior notification of the need for care and vigilance when approaching a crossing. In the paper entitled " Railway Level Crossings " which Mr. F. Horler presented to the Institute in 1927, emphasis was given to the need for road signs to be of a standard design so that all who see them will recognise their import. Since that date, International road signs have been agreed upon and adopted throughout the United Kingdom.

On the rail approaches to gated public road crossings the " stop " and/or " distant " signals of course, provide the advance warning to locomotive drivers. On the road approaches to such crossings the standard warning sign shown in fig. 4 (*a*) is provided by the Highway Authorities. This conforms to the requirements of The Traffic Signs Regulations Act of 1950 and is commonly used on the Continent of Europe. Reflectors are incorporated in the road signs where considered desirable.

On the rail approaches to ungated public road crossings, speed reduction and whistle boards are provided by the railways to meet the Ministry of Transport's requirements. On each road approach to these crossings a warning sign of the type shown in fig. 4 (*b*) is placed at least 150 yds. from the crossing by the Highway Authorities. A further warning sign bearing the legend

" trains cross here " as shown in fig. 4 (*c*) is fixed immediately on each side of the crossing by the railways. It is the Highway Authorities' responsibility to ensure that the good view of the railway is given in each direction on each road approach.

The level crossing arrangements recently installed by the North Eastern Region at Warthill constitute a major change in British practice and could form the basis of modernisation elsewhere. At that location experimental mechanical lifting barriers have for the first time in the United Kingdom been installed on a level crossing of a railway and public road, the arrangements being as shown in fig. 5. The road crosses the railway at an angle of 30° from normal ; the crossing is protected by " distant " and " home " signals and there are an average of 20 trains and 100 vehicles per day over it. It is understood that steps were taken to legalise the use of barriers by Section 72 of the L.N.E.R. Act of 1947.

The two 30-ft. barriers are of tubular steel construction, each 12-in. in diameter at one end tapering to 5-in. diameter at the other and equipped with a fringe made up of light alloy rods. The barriers are painted white and the fringes black and white. Reflectors are placed at 2-ft. intervals along the barrier arms. The barriers are slightly over-counterbalanced so that they will rise to an angle of 45° if disconnected and are supported on welded steel pedestals. They are controlled mechanically from a gate wheel in the adjacent signal box through a rack and pinion movement, the connections being suitably guarded.

The two barriers have replaced four gates and consequently there has been a reduction in the number of connections to be made with the result that a saving in maintenance costs should be effected. The barriers have been arranged to work in opposite directions in order to balance out wind resistance. Furthermore, their positioning is such that if a road vehicle should run into them and bend them towards the railway, a train would trail pass them. Arrangements are provided for detecting and locking the barriers in the horizontal position before the rail signals can be cleared. Wicket gates have been retained for the use of pedestrians.

In addition to the barriers shown in fig. 6, the following protective devices have been provided :—

(*a*) Standard advance road warning signs.

(*b*) Two revolving " stop " boards 3-ft. in diameter illuminated at night placed 11-ft. above road level one on each side of the crossing facing the road traffic. These are controlled by a lever in the signal box and rotate through 90° so that they only face road traffic when the barriers are about to be lowered. They are only floodlit when facing the road.

(*c*) Six red lights, three on each side of the crossing. One of these is placed in the centre of each barrier arm and illuminated whilst the barrier is being lowered and all the time that it is down

The other four are fixed in two pairs, one pair on each side of the road. The lamps of each pair are placed side by side 10-ft. above road level on the " stop " board post. These are arranged to flash alternately at 1 sec. intervals whilst the barriers are being lowered ; when the barriers are detected and locked in position, one lamp of each pair is extinguished whilst the other is left steadily illuminated.

(*d*) Floodlighting designed to illuminate the crossing during hours of darkness.

(*e*) Cattle grids at each side of the roadway over the crossing to prevent animals from straying on to the lines.

(*f*) Trickle charged batteries for lighting the red lamps as a precaution against power supply failure.

It is understood that the Ministry of Transport have indicated that they are satisfied with the arrangements and that in fact they consider them to be unnecessarily elaborate in certain respects.

Private Crossing Arrangements

At accommodation or occupation crossings the railways are legally obliged only to maintain the fencing and gates and the roadway between the gates.

At such locations single span wooden gates and cattle grids are provided. The gates are always hung so as to open away from the railway and are usually of the self-closing type. It is the crossing user's responsibility however, to ensure that they are closed properly ; warning notices are invariably fixed on each side of the crossing to draw attention to the fact that a fine of 40/- will be incurred by anyone found guilty of leaving the gates open.

Furthermore, it is the user's responsibility at all times to satisfy himself that conditions are safe for him to proceed across the railway before commencing to do so. In some instances telephones are provided to enable crossing users to contact the nearest signal box at any time in order to ascertain whether it is safe for them to use the crossing.

The gates are usually set back from the railway in order to provide a safety bay for any vehicle that might become trapped within the crossing. In practice however, it is very often found that these do not give sufficient clearance for the modern types of farming appliances in use today. Likewise, the gates although providing adequate openings for their original purpose are often barely wide enough for the combined harvesters, etc., that have to pass through them now. Users are therefore encouraged to open the gates on both sides of the crossing and to make certain that the gate openings are wide enough before taking their vehicles over.

British Railways Rule 107*b* requires stationmasters to request and encourage users of accommodation and occupation crossings to notify them when heavy appliances are about to be taken over the lines so that suitable precautions can be taken by the station operating staff. It is understood that in general the crossing users co-operate in this respect ; there would appear to be no legal obligation however, for them to do so and it is not clear as to whether any action could be taken against them should they fail to follow this course.

An accident which occurred at Court Sart Farm occupation level crossing on the Western Region on the 9th October, 1952, typifies the problems that exist and the dangers that are ever present at crossings of this type. On that occasion a heavy articulated motor lorry which was being driven over the crossing had stopped with its rear end on the track. The driver had opened both gates in the approved manner but had had difficulty in negotiating a passage through the far side gateway. The gates were set well back but the safety bay was too short for the lorry to stand clear of the line. A few seconds after the lorry had stopped a passenger train travelling at 40 m.p.h. struck it and was completely derailed, the engine falling over on its side on the foot of the embankment. Although telephonic communication with the nearest signal box was available, the lorry driver was unaware of the existence of same and had not therefore enquired as to whether it was safe for him to take his vehicle across. Fortunately there were no serious casualties.

It is understood that at such locations the railways are always willing to widen the gates to suit the modern requirements providing the users meet all expenses incurred by the change. If the railways decide to install additional equipment to safeguard such crossings, they legally accept responsibility and admit liability for any accidents that might occur at such locations thereafter.

In the Report which Messrs. G. Matthews and S. Williams presented to the International Railway Congress Association in Stockholm in 1952, it was stated that over 700 of these occupation crossings carry road traffic greatly differing in volume and character from that for which they were originally provided, also that over 200 of them have become in substance, though not legally, public crossings. The problem is certainly a very complex one.

Part II

LEVEL CROSSING ARRANGEMENTS OUTSIDE THE UNITED KINGDOM

From the following survey of the methods adopted in other parts of the World, it might be assumed that the majority of the level crossings are protected by means of the devices of which details are given. Such an inference would be quite incorrect. In actual fact, by far the greater proportion of the crossings are of the open type equipped only with fixed warning signs on the rail and road approaches to them. In order to provide a comprehensive picture of the position obtaining abroad, Appendix "A" to this paper shows the extent to which protection is employed in many of the countries.

U.S.A. Practice

Judged on modern standards, the United States of America have probably the most up-to-date system of crossing protection in service at the moment. It is interesting therefore, to study the developments which have led to their present day devices, some of which can be seen in fig. 7. It should be remembered that in the United Kingdom railway tracks have been fenced in since their inception. Where rail/road crossings occurred therefore, the natural solution for protecting movements over them, was to fill in the gaps in the fences by providing gates. In the United States of America however, the railways go for miles over open territory without any fencing whatsoever and consequently when the need for level crossing protection became evident it would have been illogical for gates to be used.

In the early stages a man on horseback preceded each train and the railways were content to rely upon him to provide adequate warning for road users at level crossings. Later, arrangements were made for an attendant with a red flag and red lamp always to be stationed at the more important crossings.

The first hand operated barrier was introduced *circa* 1870 and around that time a variety of road warning signs began to appear bearing legends such as " stop, look and listen," or " look out for locomotive."

The year 1889 saw the introduction of the automatic crossing bell.

The first automatic flag man or " wig-wag " signal was developed in the year 1913. This device is shown in fig. 8 and indicates the approach of a train by swinging a red banner upon which appears the word " stop " and by displaying a red light attached to the end of the banner. The arm to which the banner and light are attached swings out away from its support at the rate of between 30-45 per minute and is intended to simulate the action of a man swinging a red lamp. When no train is approaching, the banner is held between two screens on which is painted " look, listen " or other suitable inscription and the lamp suspended from the banner is extinguished. The oscillating portion consists of two electro-magnets which are alternately energised, the motion thereby given to the armature being transmitted to the banner. The motion of the banner itself actuates a circuit controller which causes the magnets to be alternately energised. The banner when in the proceed position and out of sight behind the screen, is held there by means of a latching device actuated by a third electro-magnet which is energised to give the proceed indication. This signal is designed to give a right side failure.

By 1923, the number of warning devices in service were numerous. Some attempted to scare the drivers into stopping. whilst others were designed to wreck their cars if they did not stop. The Signal Section of the Association of American Railroads, appreciating the greater hazards that then existed, attempted to restore order out of chaos by standardisation. In that year they recommended "That an electrically or mechanically operated signal used for the protection of highway traffic at railroad crossings shall present towards the roadway, when indicating the approach of a train, the appearance of a horizontally swinging red light and/or disc."

After a further survey in 1930 the Signal Section of the A.A.R. found that 60 different devices were still being used on the various railways. Realising that for all types of protection it is essential to educate the public in the proper observance of the devices provided and that to this end the situation must be simplified by standardisation in methods, equipment and practice wherever possible, a joint committe was set up to examine and co-ordinate practices between railways and public authorities. They found that two signals were generally favoured, the " wig-wag " and the flashing light signals. These were therefore recommended.

Since 1930 the " wig-wag " has dropped out of favour with the result that today practically 100 per cent use is made of two horizontal lights flashing alternately ; no doubt because of the simplicity of such an arrangement and its absence of moving parts. The lamp units are always fixed at 30-in. centres and provided with 20-in. diameter backgrounds. The speed of flashing is between 30 minimum or 45 maximum flashes per minute. Again, this timing is based upon the desire to make the lamps correspond with the appearance of a swinging red lantern. The timing is considered by some to be too slow to be effective as it is their contention that a faster moving light would attract the attention of motorists more effectively.

Rotating stop signs are used in some States and barriers in all States where considered necessary as adjuncts to the flashing lights.

Light Units

The light signals are considered the essential part of the protective equipment. Originally simple devices with small $5\frac{3}{8}$-in. diameter lenses were employed. They were not very efficient optically but still adequate for the type of traffic that existed at that time.

With the increase in volume of road traffic and the higher speeds attained on the railways, a stronger indication and better close-up indication was found to be necessary. Thus in 1930 the design was amended to incorporate a different type of optical system using reflectors with a backlight attachment suspended below and at the back of the main unit so that motorists could get a close-up indication by looking at the signals located on the far side of the crossing.

Since then the designs have been further amended to give even greater beam intensity. The present design is shown in fig. 9 and is equipped with a $8\frac{3}{8}$-in. diameter roundel to give 30° horizontal spread and an indication having a beam candle-power of even intensity at any angle up to 10° on either side of the axis, the range at any point within the 20° angle under bright sunlight conditions, with the sun at or near the zenith, being not less than 1,500-ft. When these more powerful units became available, there was also established the practice of having four of these units facing approaching traffic, two on the near side of the crossing to the right of the roadway and two on the far side of the crossing and the roadway. Consequently every signal now has a counterpart as a backlight and there should be no excuse for a driver to miss the warning.

The lights are mounted not less than 7-ft. nor more than 9-ft. above road level. Where conditions make it necessary for signals to be mounted at higher levels, say on 20-ft. cantilever structure, special glassware is provided.

The lamps most commonly used for these units are 10 volt 18 watt single filament, although 11 volt 11 watt single filament lamps are sometimes employed. Regular inspection by railway personnel and the use of high quality signal lamps are the only precaution taken against lamp failures. All light units however, have clear sidelight windows facing rail traffic so that locomotive drivers can observe that they are working correctly and if necessary, report failures.

Electric Bells

Electric bells are provided at some level crossings to augment the light signals. The size and range of such bells is determined by local conditions. They are usually regarded unfavourably in residential districts. The higher speeds obtaining today on the roads and the increased use of closed cars diminishes the advantages to be obtained from bells for motorists. Bells are chiefly beneficial to pedestrians and children.

Assembly Details

The light units as mentioned previously, are fixed in horizontal pairs at 30-in. centres. They are mounted on a 4-in. or 5-in. outside diameter post, as shown in fig. 10, the post and fittings being painted white or aluminium except for the light unit display boards which are painted matt black.

The posts also carry a number of legends. At the top of the assembly a railroad crossing sign is provided. This is known as a cross buck sign and is believed to owe its origin to the fact that earlier signs portrayed a skull and crossbones to frighten people into obeying the signal displayed.

Where multiple track is concerned, a further sign is fixed between the cross buck sign and the light units to indicate the number of tracks to be crossed. This is considered to be very desirable since motorists waiting for a train to pass, might proceed as soon as they see it clear the crossing without bothering to look at the lights to see whether their path is actually clear. The sign therefore serves as a reminder that even though one train has gone, another might be approaching from the other direction.

Finally, a sign is fixed below the light units to warn road users to stop if a red lamp is alight even though it may not be flashing. This is because flasher relays are used to operate the light units and the circuits are so arranged that should the flasher relay fail to start operating, one of the lamps will be continuously lighted. If the lamps are flashing or if one lamp only is alight, the road users know that a train can be expected.

Reflectors or reflective materials are incorporated on the signs where considered desirable.

In some instances the stop on red signal sign is replaced as shown in fig. 11, by what can be regarded as a 4-aspect signal with four red lenses bearing the letters S, T, O and P respectively. It is usually arranged for these to be illuminated intermittently in unison with the flashing light signals.

A bell, if required, is mounted on the top of the post with the face of its gong parallel to the roadway.

A minimum of 20 to 30 seconds warning is given for maximum speed trains on single or double track. Where there are more tracks or the road and railway meet at an acute angle, the minimum time is extended to permit slow moving road vehicles to clear the crossing. The signals operate until the rear of the train clears the crossing. Unless speed measuring circuits are employed, trains moving at less than maximum speed will lengthen the warning period. Usually warning times in excess of one minute are considered objectionable where road traffic is heavy.

The essence of good protection is a short warning period, the road users being educated to realise that immediate response to the warning is essential.

Barriers

A barrier as used in the U.S.A. can best be defined as a light wooden arm moving in a vertical plane which is lowered across all or part of the road as a psychological barrier to road traffic. Its construction is such that it can be broken easily by a road vehicle, as can be seen from the details given on fig. 12.

The barriers are arranged either for mechanical or power operation. In general, the former is used where a keeper is in attendance at the crossing. Manually controlled barriers may extend fully or partly across the road depending upon the width of the road and other factors.

Automatic barriers are used solely as adjuncts to flashing light signals, and they extend over only half the roadway. Two are provided at each crossing location, one on each side of the crossing facing the approaching traffic. It is not considered desirable for such barriers to span the entire roadway because of the likelihood of shutting a car in the crossing and the possibility of a motorist in such an eventuality not having the presence of mind to crash through the barrier.

Each barrier arm is painted on both sides with alternate diagonal stripes of black and white and equipped with not less than three miniature red lamps arranged to shine in both directions, along the roadway. The lamps are illuminated from the time the arm starts to descend until it is restored to its vertical position once more, the one nearest the tip of the arm being steadily illuminated, whilst the other two flash alternately in unison with the main flashing light signals.

The barrier mechanisms use low voltage d.c. motors and are so designed that their associated arms will assume a horizontal position across the roadway in the event of a power supply failure. In addition, provision is made to ensure that should an arm encounter an obstacle whilst it is being lowered or raised, the machine will stop at once and remain in that position until the obstacle is removed, after which it will assume a position corresponding to the controls.

The mechanisms are designed to ensure that their associated arms will be lifted from their horizontal to their vertical positions within 11 secs. to 40 secs. maximum depending upon the voltage applied to them. They are required to be adjustable to permit their arms to descend from their vertical to their horizontal positions smoothly and evenly in 10 seconds to 15 seconds.

The mechanisms are arranged either for post or pedestal fixing and usually form part of the flashing light signal assembly as shown in fig. 13. In this case the fittings on the post are modified to allow the barrier arm in its vertical position to clear the backs of the light signals and signs. The barrier machines can however, be mounted separately but adjacent to their associated crossing signals where local conditions demand such a course be adopted. The arms when lowered are not less than 3-ft. 6-in. nor more than 4-ft. 6-in. above the crown of the road.

The circuits for automatic barriers are designed to ensure that the arms will not commence their descent until at least 3 seconds after the flashing lights have commenced to operate, and that they will reach their horizontal position before a train travelling at maximum permitted speed can arrive at the crossing. They have to remain lowered until the rear of the train has cleared the crossing.

If a bell is incorporated on the signal assembly, arrangements are usually made for it to commence ringing as soon as the flashing lights start to operate and to continue until the barrier arm is within 5° of the horizontal.

Where multiple tracks are concerned, barriers undoubtedly help to prevent motorists trying to rush across when one train has left, despite the fact that a second train might be coming in the other direction.

At some locations short arm barriers are provided to obstruct the pathway for pedestrians. Most barrier machines are designed to enable such an attachment to be provided if required.

Power Supplies

The most common form of power supply in use, comprises a storage battery system charged by a transformer/rectifier unit direct from the a.c. mains. The supply to the lamps and machines is taken normally from the rectifier and transferred to the battery by means of power-off relays in the event of a mains failure.

Where no a.c. is available, primary battery operation is used. It is usual to install two batteries in parallel at such locations in order to permit maintenance renewals to be carried out without dislocation of service. The second battery does of course, also serve as a standby.

There are few automatic barriers operating on primary batteries ; where road traffic is heavy enough to justify barriers, there is usually sufficient population concentration that a.c. power will be available.

Control Equipment Flasher Relays

One of the essential pieces of apparatus for an automatic level crossing warning signal system is, of course, a flasher relay. Several types are in existence either for operation on a.c. or d.c., the latter being more commonly employed. One type of d.c. flasher relay that is available is shown diagrammatically in fig. 14 and takes the form of a neutral relay having four coils arranged in two pairs, over the pole pieces of which is pivoted an oscillating armature with at least three sets of contacts. Two sets, one at each end, are for controlling the lamps and one set in the middle comprises the operating contacts. When de-energised, the armature is biased to close the left-hand operating contact. The action of the operating contact is to shunt out the pair of coils on one side so that current flows only through the opposite pair and attracts the armature so as to close the opposite operating contact. The first pair of coils is then connected in circuit and the second pair shunted and the armature therefore continues to oscillate and close alternately the lamp contacts as long as the coil terminals are connected in the control circuit. The speed of flashing is adjusted by varying the air gap.

Interlocking Relays

For single line crossing schemes another type of relay that is in common use is the d.c. interlocking relay. This is shown in fig. 15 and comprises essentially two neutral relays mounted in a common case, the armatures of which are allowed to interfere mechanically with each other through a pawl. The arrangements are designed to ensure that only one armature can make its back contact at one time, even though both sets of coils are de-energised, the purpose of which will be evident later when the circuit arrangements are considered.

The pawl normally hangs in a vertical position when both armatures are energised, the arms then being in the position shown in fig. 15*a*. When, for example. the left-hand coils are de-energised as shown in fig. 15*b*, the top of the locking piece on the left-hand arm in falling engages with the locking pawl and throws it to the right so that it engages with the top and bottom of the locking piece on the right-hand arm. The arm is therefore held up even though the right-hand coils subsequently de-energise but as will be seen from fig. 15*c*, in such an event all the contacts on the right-hand side both front and back, will be opened. If the left-hand coils are re-energised whilst the right-hand coils are still de-energised, the weight of the right-hand arm will still hold the pawl in the locking position, and prevent the right-hand back contacts from making. The relay will only be restored to its normal interlocked position when both sets of coils are energised. It will be seen that the locking is effected by the weight of the arms ; the magnetic pull on armatures does not enter into consideration.

Track Circuits

As is to be expected, the track circuit forms the fundamental basis for most automatic signalling schemes since it can be made to detect the presence of trains approaching the crossing. Treadles can be employed to provide similar facilities but they are not favoured because of their comparative unreliability and the fact that they will not detect stranded vehicles or broken rails. With certain types of treadles there is always the danger too that persons may stand on them to release the associated circuits. As a general rule therefore, they are used only when the local conditions are such that the installation and maintenance of track circuits would be difficult and expensive.

Track circuits are of the d.c. or a.c. type depending upon local power supply facilities, electrified territories, etc.

Circuit Arrangements

Single Track Using Conventional Track Circuits

Fig. 16 shows a method commonly used on single line sections and makes use of the conventional d.c. track circuits, the two d.c. neutral relay components of the interlocking relay being used as track relays. In the diagram, both relays are shown in their normally energised positions. Assume now that a train approaches and occupies TC "A." Relay ATR will thereupon become de-energised and make its back contacts and through them a circuit to the flasher relay, lights and bell. The flasher relay will then commence to oscillate and will short-circuit one lamp of each pair alternately, thus applying full voltage to the other. This arrangement is preferred rather than one which would open and close the circuit to the lamps, since it reduces the arcing which would occur if the load were broken each time and which would result in extreme wear in relay contacts and short contact life. The flashing will continue until the train clears TC "A" whereupon ATR will re-energise and by opening its back contacts, will discontinue the warning at the crossing by breaking the circuit to the flasher relay, lights and bell.

Because of the interlocking feature described earlier, BTR will not be permitted to make its back contacts when TC " B " becomes occupied. It will be evident that if they were allowed to make, the warning would continue until the train had cleared TC " B."

It will be noticed that with the arrangements shown, if the flasher relay becomes disconnected, one lamp of each pair will be kept permanently alight.

The manner in which the rail joint insulations are placed adjacent to the crossing is worthy of note. It will be obvious that rail joint insulations would suffer if they were installed in the middle of the roadway in order to provide an equal warning period for both directions. An alternative would be to place the rail joints adjacent to each other on one or the other side of the crossing ; this however, would cause the warning devices to operate until the train has cleared the crossing for trains in one direction but would stop them with the train on the crossing when travelling in the other direction. Theoretically in the latter instance, it should be abundantly clear to a motorist waiting at the crossing that his path is obstructed despite the fact that the warning signals have ceased ; the danger is, of course, in respect to a motorist approaching the crossing. For this reason as mentioned earlier, the warnings have to continue until a train clears the crossing, irrespective of the direction in which it is travelling. With the arrangements shown in fig. 16, the making of the back contacts of either relay produces a common rail arrangement and extends the track circuit concerned to cover the crossing.

Single Track Using Westrak Track Circuits

An interesting variation of track circuit control on single lines is shown in fig. 17. This employs an arrangement known in the United Kingdom as a Westrak track circuit which relies on a rectifier unit placed at the extreme end of the track section to divert alternate half-cycles of the a.c. supply and so cause pulting d.c. to flow through the track relay located adjacent to the feed transformer. Such an arrangement has the advantage that all the control equipment with the exception of the rectifier, can be located at the crossing and of course, renders line wire unnecessary.

The rectifier unit is mounted between the rails in a weatherproof cast-iron case and requires little or no attention. In all other respects, the arrangements follow those described earlier.

Special Requirements

So far straightforward crossing protection schemes have only been considered. In laying out arrangements of this kind however, local conditions often require special controls. For instance, at some locations means have to be provided to permit manual operation of protection equipment which normally works automatically. At some crossings no left turn or no right turn signals have to be installed for roads running parallel to the railway.

At crossings in close proximity to sidings where shunting is carried out or to stations where trains stop regularly, means have to be provided for cutting out the operations of the automatic crossing warning devices. Various schemes are in operation ranging from automatic time cut-outs to elaborate schemes of manual or auto-manual supervisory control. In territories where there is a big difference between the speed of the fastest and slowest train, it is sometimes considered desirable to provide timing track circuits in order to ensure that the same warning period will be given no matter at what speed a train is approaching. Care must be taken to ensure that timing circuits are so arranged that a failure of a timing device will result in the full approach control becoming effective.

In order to cater for the possibility of modified controls being required at a later date, the modern tendency is to use directional stick relays in preference to interlocking relays, since the former provide greater flexibility for making changes. Furthermore, the provision of a short track circuit spanning each crossing has now become almost standard; this rarely extends more than 100 feet on each side of the crossing.

Automatic Barrier Controls

Several directional stick circuit arrangements are in service, the principal difference between each being the time during which the stick relay is energised. In some instances the circuit to the stick relay is prepared by the occupation of the approach track circuit but not completed until the train arrives on the crossing track circuit. In others the stick relay is energised as soon as the approach track is occupied and maintained in that position until the leaving track circuit has been occupied and cleared. Such an arrangement is depicted in fig. 18, which details the wiring requirements for a level crossing on a single line section employing flashing lights, automatic barriers and warning bell.

The barrier machine that has been selected for the example in question, is of the type in which the barrier arm is raised from the horizontal to the vertical position by an electric motor through a train of gears and is held in the vertical position by means of a solenoid operated band brake. This brake is fitted to one end of the motor spindle by means of a ratchet mechanism which trails whilst the arm is being raised. The brake solenoid has two windings, YR1 of low resistance to engage the brake and YR2 of high resistance which is placed in series with YR1 as soon as the arm is raised, thus economising the current used in holding the arm vertical. In addition to the brake, the solenoid operates a set of contacts, one closed when energised and one other closed when de-energised.

With no train in section, the flasher relay will be at rest, the flashing lights extinguished, the bell silent and the barrier arms held in their vertical position by their brake solenoid windings YR1 and YR2 in series. Relays XR (which operates the bell), XPR (which controls the barriers) and XGPR (which sets the flashing lights in operation) will be standing energised whilst the directional stick relays ES and WS will be standing de-energised.

Assuming now that a train travelling from West to East approaches the crossing and occupies TC "A." A circuit will then be completed over CTR front, ATR back, WS back contacts to energise the eastbound stick relay ES. Relay ES will remain energised over this circuit until the train reaches the crossing TC " B," whereupon a stick circuit for ES will be completed over BTR back and ES front contacts. When the train has occupied TC " C " and has cleared TC "A," the stick circuit for ES will be completed over ATR front, CTR back, ES front contacts ; that condition will continue until the train leaves TC " C " at which time ES will become de-energised. Due to its slow release feature, ES is unlikely to drop away during this sequence of working because of a temporary loss of shunt causing the track relays to bob.

The warning devices cannot be controlled directly over contacts of the ES and WS relays ; if this were done, the warning would commence with the occupation of the entrance track circuit and would continue until the leaving one had been cleared. A separate control relay XR is therefore provided, the energising circuit for which is made up over front contacts on the three TC's "A," " B " and " C." In order to provide the directional feature however, ATR front contact is bridged out by WS front contact and CTR front contact is bridged out by ES front contact. It is usual to include a test switch in series with the control of XR to permit normal routine inspection and tests to be made on site.

Now, having established the method of directional working, it will be seen that when TC "A" is occupied by an eastbound train, XR will become de-energised, causing XGPR to release at once, XPR to release after the expiration of its slow release period and the flasher relay to start oscillating. Relay XR in dropping will start the bell ringing and XGPR will start the lights flashing as with earlier examples. The two innermost lights on each barrier arm will also flash in unison with the main light units, whilst the light unit at the end of each arm will be steadily illuminated.

Relay XPR as mentioned previously, controls the barrier machines ; the reason why it is made slow release is of course, to ensure that at least 3 seconds will elapse between the time the lights start flashing and the arms begin to descend. Until XPR opens its front contacts therefore, the barrier arms will be held in their vertical positions by the circuits through their brake windings YR1 and YR2 in series. When XPR finally de-energises therefore, the holding circuit to coils YR1 and YR2 will be broken and the arms will begin to descend by gravity, rotating their motors in the reverse direction. A regenerative braking circuit is completed in each case through a back contact of the YR in series with a resistance ; the speed of descent can therefore be adjusted by varying the value of the resistance.

When the barrier arm associated with the bell is within 5° of the horizontal position, the circuit to the bell will be broken by a barrier arm circuit controller contact ; the bell will therefore stop ringing.

When the train has cleared TCs "A" and "B," XR will become re-energised in turn causing XIR to become re-energised. A front contact on the latter will then complete the circuit to the brake solenoid windings YR1, which when energised will complete over their front contacts the circuits to their motors. The motors will then commence to rotate and the arms will begin to ascend. When each arm reaches a position 80° off the horizontal, one of its associated circuit controller contacts will open and will thus place windings YR1 and YR2 in series with each other. At 85° off the horizontal, the motor circuits will be opened by other circuit controller contacts ; the YR circuit will however, still be retained and the arms will thus be held in their vertical positions.

As soon as both arms have been proved vertical, the circuit to XGPR will be completed. When this relay is energised, the supply to the flasher relay and to the lights will be disconnected.

Multiple Track Controls

In the preceding examples only single line sections have been considered. The arrangements in multiple track territory follow somewhat similar lines but are not of course, complicated by the fact that the direction of the traffic has first to be established before the warning devices are set in motion. At busy locations provision is sometimes made to extend the approach controls for the warning devices if two or more trains are approaching the crossing from opposite directions at the same time. Thus, although the standard warning period would apply for the first train to enter the section, a more lengthy warning would be given for the second train. In some instances, particularly where flashing light signals are the only warning devices installed, additional illuminated stencil indicators are provided bearing the legend "two trains," the lighting circuits to these being so arranged that they will be illuminated when more than one train is approaching the crossing.

Advance Warning Signs

Rail Approaches

At a suitable distance on the railway approach to each crossing, a sign is erected displaying the letter " W " or an equivalent code. This indicates to the locomotive driver that he is approaching a road crossing and that he should therefore begin blowing his train whistle in the prescribed code.

Road Approaches

The advance warning signs on the roadway approach to a crossing take the form of a circular target approximately 30-in. in diameter bearing a cross and the letters R R in black on a yellow background, as shown in fig 19*a*. These signs are mounted on posts at the side of the roadway at a distance of 250-ft. to 500-ft. or more from the crossing, depending upon local conditions. At some locations a square yellow sign bearing the same legend, as shown in fig. 19*b*, is painted on the roadway either in conjunction with, or in lieu of, the circular sign. Both types of sign sometimes show additionally the distance to the crossing.

Loco Headlights

One important feature that should not be overlooked when considering the methods adopted in the U.S.A. is that all locomotives in that country carry powerful headlights. It is true that these are chiefly provided in order to protect railway employees working on or near the lines because of the quieter operation obtaining with the diesel/electric locomotives now in service. The headlights do however, help considerably in warning road users of the approach of trains to crossings at night.

Types of Crossings—U.S.A.

According to reliable statistics at the 31st December, 1951, there were 227,415 level crossings on class 1 railways in the U.S.A., a class 1 railway being one with an annual gross operating revenue of 1,000,000,000 dollars or more. The extent to which the crossings are protected is detailed in Appendix "A."

From reports received, it is understood that no set system of classification is employed in determining the type of protection to be provided at each crossing. Each is considered on its own particular merits and the warning arrangements to be provided are determined by the railway concerned, usually in co-operation with the local Highway Authority.

The installation costs are borne largely by the railways themselves. For example, of the 1,385 new level crossing installations put down in 1952, 764 were paid for entirely by the railways, 544 were paid for jointly by the railways and Highway Authorities and only 77 were paid for entirely from public funds.

It is the responsibility of the railways to maintain the crossings and protective devices installed thereat and the railways therefore bear the full burden of maintenance costs.

Accidents

During the years 1949-1952 inclusive, 6,068 (average 1,517 per annum) were killed and 16,381 (average 4,095 per annum) were injured as a result of accidents at all types of level crossings in the U.S.A. It would be invidious to compare these figures with those in regard to United Kingdom accidents, since the character and volume of road and rail traffic in the two countries differ so widely.

A very comprehensive analysis of the comparative merits of the various types of crossing protection based upon actual experience of their use, was made by Mr. Wm. J. Hedley, Asst. Chief Engineer, Wabash Railroad Co., in his " Second Report on the Achievement of Grade Crossing Protection " which he presented before the 51st Annual Convention of the American Railway Engineering Association on the 11th March, 1952. In this he took into account a very large number of factors over a period of 23 years. Briefly, his findings in regard to the relative effectiveness of the different forms of protection were that they compared as listed hereunder from the most effective to the least effective :—

Automatic Barriers
Flashing Lights—Single Track
Manual Barriers—Full-time Attendants
Flashing Lights—Multiple Track
Manual Barriers—Part-time Attendants
Watchman—Full-time Attendance
Wig-Wag
Automatic Bell
Watchman—Part-time Attendance
Reflector Signs
Painted Signs

Canada

In Canada the installation of crossing protection is regulated by the Board of Transport Commissioners under the Minister of Transport, the requirements for each location being decided on its own merits. The function of the Board in this respect is :—

(i) to determine where new installations shall be made ;

(ii) to provide specifications for standard crossing protection equipment ;

(iii) to apportion the installation and maintenance charges between the Municipal or Highway Authority and the Railway.

(iv) to make contributions from the Railway Grade Crossing Fund which was set up by the State in 1919 to bear part of the cost of new installations and of substantial improvements to existing ones.

With a few minor exceptions, the protection arrangements follow closely those employed in the U.S.A. A typical installation is shown in fig. 20.

" Wig-wag " signals are still in wide use although they are gradually being replaced by flashing light signals which have now been standardised for current installations.

South America

In South America, open crossings marked by standard cross buck road warning signs predominate. Where protective devices are installed these usually take the form of hand worked mechanical barriers or automatic flashing lights, sometimes supplemented by audible warnings. In Chile, the railways are obliged by law to maintain crossing keepers in attendance at all public crossings during the hours of daylight. In Uruguay, Equinetic barrier machines are installed at some crossings. These mechanisms consist essentially of an arm pivoted freely on a rigid support, with biasing weights which can be driven through an angle relative to the arm by means of an electric motor. This has the effect of altering the centre of gravity of the mechanism and thus moves the arm. Smooth action is secured by means of oil buffer cylinders with special valves. The light signal assemblies used in this country are of very simple construction as will be evident from fig. 21.

France

On the French National Railways automatic warning devices of the type illustrated in fig. 22 are now being used to replace road barriers and crossing keepers. They provide a red light flashing at 85 times per minute when a train is approaching; in addition a movable warning placard which is divided into two halves, bearing the legend "beware of trains," faces road users under these conditions. These warnings are supplemented by the ringing of a bell in country districts. When circumstances permit the crossing to be used by road traffic, the two portions of the warning notice are moved through an angle of 90° by an electro-mechanical arrangement so that they become out of sight of the road users. For the St. Andrew's Cross and the lettering on the placard, special light reflecting paint or material is used. Treadles are employed on the rail approaches to provide automatic operation.

The arrangements are designed to enable primary batteries to be used in the country districts.

Sweden

Level crossings on the Swedish State Railways are classified by the Board of Roads and Waterways who stipulate the type of equipment to be provided. The railways are responsible for the provision and maintenance of suitable protective devices but a contribution of 90 per cent of the initial costs is obtained from the motor car taxes.

A number of crossings are equipped with lifting barriers, mechanically worked from adjacent control posts by the double wire system of transmission. A typical barrier is shown in fig. 23, from which it will be noted that a mechanical bell is incorporated which rings automatically when the barrier arm is descending.

The flashing light signal assemblies take the form shown in fig. 24*a*. The crossing sign at the top indicates whether single or multiple track is concerned. The signal displays:—

(i) a red light flashing at 80 times per minute for at least 30 seconds when a train is approaching the crossing; this is supplemented by a bell warning.

(ii) a lunar white light flashing at 40 times per minute if the crossing is clear for road traffic.

Single filament lamps are used; no precaution is taken against lamp filament failure since in such an eventuality with the crossing light out, road users are expected to satisfy themselves whether conditions are safe for them to cross.

The variation in flashing periodicity is designed to enable colour blind road users to distinguish the aspects displayed, this being a common practice on the Continent.

Special emphasis is given to the provision of advance road warning signs, these being as shown in fig. 24*b*. The International road warning sign is erected 150-250 metres from each crossing. At a distance of 8-12 metres from the crossing a cross buck sign is erected bearing the legend " Look out for trains." The distance between the triangular sign and the cross buck sign is divided into three equal parts by three intermediate signs consisting of rectangular plates carrying 3, 2 or 1 oblique bars of light reflecting material. The intermediate sign with three bars is then placed on the same post as the triangular sign.

Holland

Where protective devices are deemed desirable for public road crossings in Holland, these usually comprise lifting barriers supplemented by flashing light signal assemblies. The latter are designed on the lines shown in fig. 25. Again the crossing sign surmounting the light signal, indicates whether single or multiple track is involved. The signal itself comprises :—

(i) a red light at front and rear which flashes at 90 times per minute for at least 20-25 seconds with a train approaching the crossing, this being supplemented by a bell warning.

(ii) a lunar white light at front and rear which flashes at 45 times per minute when the crossing is clear for road traffic.

(iii) a steady orange light at front and side which is an emergency indication that the signal is out of order and that road users should therefore cross with caution.

Single filament lamps are used, those for the red and lunar white aspects being fed direct from the a.c. mains. The orange light is fed from a primary battery and is brought into commission with a power supply failure or a main signal lamp failure.

At important crossings, a yellow light repeater of the red crossing signal is placed 150 metres on the road approaches to that signal and this flashes at the rate of 90 times per minute in unison with its counterpart.

Belgium

At the more important crossings on the Belgian National Railways, barriers are provided. These are usually of the lifting type and manually worked by mechanical winch, although an electrical winch is sometimes used.

Where barriers are installed, the International road warning sign for a gated crossing is erected 200 metres on each side in advance of the crossing. No intermediate signs are provided.

At other crossings, automatic light signals of the type shown in fig. 26*a* are provided. These follow a similar pattern to those used in Sweden and display :—

(i) a red light flashing at 80 times per minute supplemented by a bell warning for at least 20 seconds with a train approaching.

(ii) a green light flashing at 40 times per minute when the crossing is clear for road traffic.

12 volt 24 watt 4 filament lamps are used, all filaments being kept connected permanently in parallel. The condition of the lamps is also repeated into the nearest signal box or station-master's office as a precaution against lamp failure.

Advance warning signs and intermediate signs as shown in fig. 26*b* are provided for all crossings other than those protected by barriers.

South Africa

In the year 1926 the South African Railways and Harbours Administration appointed a Commission to examine and report on the protection of all railway level crossings within the Union.

The Commission advocated at that time that the cost of the improvements should be borne partly by the State, and that as many crossings as possible should be eliminated. Since that report was published in 1927, the expenditure incurred up to the close of the financial year 1952/53 in connection with the elimination of level crossings and the provision of protective appliances, amounted to £2,436,335 of which £1,611,345 was borne by the Administration and £824,990 by local authorities. This formidable sum was sufficient only for the elimination of some 352 level crossings and the protection by means of flashing lights and barriers of some 239 others. Even now by far the greater majority of level crossings in the Union are open public crossings, but a systematic policy of adding protection to them is being followed.

It is understood that the intention is to provide " stop " signs at all dangerous level crossings in South Africa and that when these have been provided, road users will be obliged by law to obey them and will be subject to a heavy fine for failing to do so.

For the flashing light installations, lamp units with red front aspects and white sidelights, using single filament lamps, have been standardised, the aspects flashing at a rate of 30 times per minute.

It is understood that before the advent of flashing light signals, accidents at level crossings equipped with barriers were frequent. The barriers were often damaged by road vehicles failing to stop. The addition of flashing lights at these crossings has almost entirely eliminated this type of accident.

Burma

All level crossings in Burma are protected with manually attended hand worked gates. Some open away from the railway and some across it. They are all interlocked in one way or another with the railway signals. The manner in which this is achieved varies according to the signalling arrangements obtaining in the locality of the crossing concerned. Key locks are however, a common feature of all the methods adopted.

A typical layout is illustrated in fig. 27. The gates are not intercoupled with rodding and have therefore to be opened or closed by hand individually. For each gate there is a primary key and this is fixed to its associated gate by means of a short chain. In addition, for each pair of gates there is a common secondary key and this, when the gates are opened, is imprisoned in one of the key locks, a separate key lock being attached to each gate post in the manner shown in the diagram. Finally, one electric key transmitter is provided at the crossing and another in the nearest stationmaster's office, to enable the arrangements to be under the control of the latter.

To close the crossing to road traffic it is necessary first to shut gate " X." Primary key "A" is then inserted in the double key lock and turned, this action releasing the secondary key " B " and locking gate " X." Key " B " is then extracted from the double key lock and transferred to the triple key lock, the removal of key " B " backlocking key "A" in position. Gate " Y " is then shut and becomes locked when primary key " C " is inserted and turned in the triple key lock. With keys " B " and

" C " in the triple key lock, key " D " is released and can then be extracted and transferred to the electric key transmitter. Again the removal of key " D " backlocks keys " B " and " C " in position. When key " D " is inserted and turned in the crossing key transmitter, its counterpart in the stationmaster's office is released and can be used to free the interlocking on the crossing release slide lever at that location. That slide lever can then be put normal to release the signal and point slide levers and to backlock key " D " in position on the slide frame. The removal of the station key " D " from its transmitter backlocks crossing key " D " in its transmitter.

When conditions are such that the crossing can again be opened to road traffic, the signal and point slide levers are restored normal to free the crossing release slide lever. When the latter is pulled to its reverse position, key " D " is released and can then be extracted from the slide frame lock and inserted and turned in the stationmaster's key transmitter. Key " D " at the crossing is then released and this can, in turn, be used to free keys " B " and " C," the key " B " to free key "A." Both gates can then be opened.

No light signals are provided for road traffic. The only indication given to road users that the gates are about to be closed is the hand signal which is given by the gatekeeper prior to the closing of the gates.

India

The most common form of protection that is to be found at level crossings in India at the moment is hand worked gates, interlocked with the signals by means of key locks, generally in the manner described in regard to the Burmese railways.

At a number of locations however, lifting barriers are installed. These are worked from the nearest signal box from a special winch interlocked with the signals and points, usually by means of keys.

The railways are in fact understood to be in the process of standardising wire worked lifting barriers which can be operated by a crank arrangement in the signal box or by an electric motor if power working is desired.

At one particular location on the Western Railway, experimental lifting barriers worked through suitable connections from an all-electric point machine instead of an orthodox barrier machine have been installed to enable the railway to examine the reaction of the road users to this form of crossing protection. From information received, it is understood that these power worked barriers are working very efficiently.

New Zealand

In New Zealand the railways are responsible for the provision and maintenance of level crossing protection devices. On roads which are classified as " main highways " outside the areas of Municipal Authorities whose population exceeds 6,000, half the cost of installation and maintenance is paid by the Main Highways Board, which is a statutory body. In the areas of Municipal Authorities with a population in excess of 6,000, the Local Authority is asked to bear part of the cost. The only classification of crossings is a priority list for installation of protection equipment or improvement of existing protection.

The railways department determine the priority based on the formula :—

Number of trains $\times$ number of road vehicles $\times$ (n+1) view factor where n=number of obscured corners (maximum 4).

Gates are not provided. Protection takes the form of either full time or part time attendance of crossing keepers or automatic audible and/or visual light signals. A typical light signal assembly is depicted in fig. 28 and comprises two red lamps flashing at 30-45 times per minute.

Considerably enlarged circular display boards as shown in the diagram are frequently used to make the flashing lights more arresting, depending upon the visibility of same. The posts and sometimes the bells and relay houses are painted with diagonal red and white " barber's pole " stripes. Road users are obliged by legislation when approaching a crossing, to reduce speed when within 100 yards of it to a rate not exceeding 15 m.p.h. They are also compelled in certain instances to bring their vehicles to a stand, clear of the crossing, and then to make adequate observations to ascertain whether or not the line is clear. Any persons found contravening this and certain other regulations are liable on conviction to a fine not exceeding £50.

Australia

The majority of the level crossings in Australia are open continuously to both road and rail traffic and are protected only by the provision of fixed warning signs to indicate the existence of the crossings.

Where traffic conditions render the provision of some other form of protection desirable, this varies according to the railways concerned but is generally afforded by the installation of swinging gates. Most of these are worked by hand chiefly by the road users themselves but sometimes by attendants. In a few instances they are worked by rodding from the nearest signal box in accordance with the conventional United Kingdom practice. Power operation is not used.

On the New South Wales Government Railways, barriers are used at a number of locations. These are worked either by hand, mechanically, electro-hydraulically, electro-pneumatically or all-electrically. A typical installation is shown in fig. 29. In this connection it is perhaps interesting to note that when the New South Wales Railways first installed barriers, they were all of steel construction. They have since been replaced however, by composite barriers consisting of short steel channel sections to which are bolted soft wooden timber flitches to form the main portion of the barrier. This change was the result of an experience where a steel barrier which had been run through by a heavy motor lorry was so badly bent that it fouled the railway. There were no local facilities available to straighten the barrier or to remove it from service immediately. All road and rail traffic was therefore held up until the district officer was able to persuade a lorry driver to attach his vehicle to the end of the bent barrier in order to move it sufficiently to enable road and rail traffic to proceed.

Flashing light signals, with or without bells, similar to those found in the U.S.A. are used at a number of crossings on all railways. The Victorian Railways have some "wig-wags" still in service but they are dropping out of favour. Likewise, the N.S.W. Railways have a number of Pearson signals still in commission. One such device is shown in fig. 30. The windmill-like apparatus at the top of the post is gear-driven by a motor mounted at the base of the assembly. When a train is approaching the crossing, the arms are driven around and a small lamp at the end of each arm is illuminated. In addition, at the back of each arm there is a loose ring on a stud which, when the arms are revolving, is thrown out by centrifugal force and strikes a gong as the arms rotate, thus giving an audible as well as a visual signal. When the crossing is clear for road traffic the arms are stationary, thus the possibility exists of a false clear signal being given and this is undoubtedly why the signal is obsolescent.

PART III

POSSIBLE IMPROVEMENT TO UNITED KINGDOM PRACTICE

In view of the change that has taken place in regard to the character, weight, density and speed of the rail and road traffic since the present United Kingdom level crossing measures were first devised, it seems logical to assume that the arrangements warrant reconsideration. It is true that in recent years the death roll at level crossings has been low when compared to that on the roads. The figure of 38 persons killed per annum on an average at level crossings is nonetheless alarming; that it is no higher, is probably fortuitous. The potential risk is certainly very much greater than it was; this is borne out by the fact that during the years 1922-1925 that average was something of the order of 12. Apathy should not therefore, be allowed to prevail.

New or additional forms of protection would it is thought, go a long way towards minimising the risk of accidents. It is realised that no matter what devices are used, it would still be virtually impossible to cater for the careless road user. Because of the shortcomings of the human element, there can be no doubt that the maximum protection to rail and road traffic with the minimum delay to each will only be afforded by the elimination of all level crossings. As valuable as human life is however, the cost of over-bridging or under-bridging the crossings would be prohibitive. Protective devices must therefore suffice.

The introduction of modifications to the existing arrangements would be a formidable undertaking. If it were embarked upon, an attempt would need to be made at the same time to effect economies from the maintenance viewpoint.

Gated Public Road Crossings

The query is often raised as to whether the cumbersome gates at present in commission at public road level crossings are really essential and whether an obstruction of lighter construction would prove equally satisfactory.

The gates certainly provide a substantial reminder to the motorist that his way is barred. On the other hand, one would imagine that our ancestral legislators had in mind when designing the gates, that they should be high enough to prevent horses jumping over them and to prevent vehicles breaking through them. In those days traffic was usually of the horse drawn variety and irrespective of any oversight or recklessness on the part of the driver, there was always one member of the party with sufficient " horse sense " not to attempt to cross when the path was obstructed. There is no danger at the moment, of cars jumping over the gates but with the heavier vehicles now on the roads, there is a very real danger of them breaking through and becoming immobile in the path of fast moving trains. It is doubtful whether any practical form of gates or barriers could be designed to prevent such an eventuality. It would seem reasonable to suppose therefore, that lightweight barriers could be used with equal success. Such barriers, if equipped with light units would be quite as conspicuous as the present day gates.

Before barriers could become standardised, the law in regard to the total enclosure of the road would of course, have to be annulled. From a reading of the Act of 1863 it would appear that the legislators were more concerned about the possibility of cattle and horses straying on to the lines rather than pedestrians. If that is the case, then if cattle grids are considered adequate protection against straying cattle at accommodation and occupation crossings, where surely the presence of cattle is more likely than at public road crossings, it seems logical that cattle grids should suffice for public road crossings as well.

In view of the fact that the Ministry of Transport have given permission for the experimental lifting barriers to be installed at Warthill, it would appear that they are of the opinion that such arrangements would be quite satisfactory under certain conditions.

It is not for one moment suggested that the gates should be discarded at once. If however, the principle could be established that barriers would suffice, they could be introduced gradually as and when gate installations come up for renewal. Meanwhile, some benefits might be derived if the gates were painted at more frequent intervals to render them more conspicuous : the use of light reflecting paint might prove advantageous. Furthermore, if red targets and red lamps are considered a desirable means for identifying level crossing gates, legislation could be introduced if necessary, to enforce the fitting of such equipment. Consideration could be given too, to the lighting of the lamps by electricity rather than by oil.

If barriers could be adopted, they would dispense with the need for rail and road stops. Mechanically operated barriers would reduce the number of connections and would thus effect economy in maintenance costs. Power operated barriers would go one stage further and eliminate all rod connections with obvious advantages and economics. Some decision would have to be taken as to whether a plain barrier arm would be adequate or whether fringes would need to be provided to prevent persons from crawling under the barriers. Practice elsewhere tends towards the omission of fringes.

At level crossings where road traffic signals are considered desirable, thought could be given to replacing these by flashing lights to distinguish them from those used at ordinary road intersections. Flashing lights have been introduced recently for some pedestrian crossings and it is understood that they have proved very successful. From this it seems logical to assume that the public would soon educate themselves in regard to the respect they should pay to flashing lights at level crossings.

Another aspect of crossing protection that could be examined is whether intermediate road warning signs would be helpful. There is no doubt that under ideal circumstances one advance warning sign should be sufficient. A number of factors have however, to be taken into account, such as an obstruction to the approach, contour of the country, etc., and in practice it is often found that the ideal warning distance is not usually possible.

Ungated Public Road Crossings

At ungated public road crossings, the possibility of providing compulsory halt signs could be examined. In addition some advantage might be gained by installing automatic flashing light signals at some of the busiest of these crossings in an attempt to educate the public to this form of protection and to assess their reaction to it. Furthermore, intermediate road warning signs might also be helpful.

Accommodation Crossings

At the field to field type of crossing the adoption of key locking arrangements somewhat on the lines of those employed in Burma and India might prove beneficial. The arrangements could be such that the crossing user would always have to telephone to the nearest signal box to obtain permission to open the gates. The signalman could then release the crossing key through the electric key transmitter system. Means would need to be provided to enable the user to return over the railway lines on foot after taking his vehicle across in order to replace the key in its transmitter. A stile adjacent to each gate could conceivably serve this purpose and still prevent cattle from straying on to the lines. Such arrangements would, of course, be open to abuse ; it would be difficult for instance to incorporate means to ensure that the user will lock both gates and restore the key to its transmitter after using the crossing. Regulations could nevertheless be drawn up to render the user liable to a very heavy fine under such circumstances. Furthermore, the signalman could be given an emergency release for use in such an eventuality and rules could be instituted to permit him to allow trains to proceed, providing he stops any train approaching the crossing and warns the driver to be vigilant at that point in case a vehicle is in fact still fouling it.

Occupation Crossings

Occupation crossings are undoubtedly the biggest menace at the present time. As a number of these have in substance if not legally acquired public status through the years, some benefit might be derived by equipping them with automatic barriers and flashing lights in order to obtain concrete evidence of the efficacy of such arrangements.

The crossings at the present moment are provided with gates which can be opened at all times and which can be, as they are, sometimes left open. At worst, the barriers would provide equal protection ; in actual practice however, they should prove instrumental in eliminating a number of accidents that do now occur.

On the 31st May, 1949, the Liberal National Member for Huntingdon asked the Minister of Transport in the House of Commons what steps were proposed to take to prevent accidents at level crossings, particularly in regard to occupation crossings.

In his reply the Minister stated that the problem of safety at such crossings had been under consideration before the war and that consequently he proposed to follow the matter up afresh in conjunction with the British Transport Commission. From more recent statements in the House, it is understood that the report can be expected in the near future. It will be interesting therefore to see what improvements are recommended.

Cost of Modifications and Additions

Any improvements and modifications to the existing arrangements would obviously entail considerable expense ; it would be unreasonable to expect the Railways to bear the cost of their introduction. Taking into consideration the changed nature of the road traffic and the fact that the Railways have now become Nationalised, it would seem equitable that a special State grant should be made for use in this connection. A precedent has already been set in other countries. It is suggested therefore, that as this problem is so tied up with the roads, a grant could be made from the Road Fund to facilitate and expedite modernisation at level crossings. Whilst the elimination of as many crossings as possible should be the ultimate ambition, the practical immediate solution would seem to be that legislation should be introduced to :—

(1) Restrict any new crossings.

(2) Re-route road traffic wherever possible to permit some of the existing crossings to be closed.

(3) Empower the State to take over those Private Occupation Crossings that have acquired a Public status.

(4) Permit some relaxation in regard to the necessity for totally enclosing the railway at certain public road crossings.

(5) Provide sufficient funds to permit the installation of improved protection facilities, the Ministry of Transport to establish the priority of the locations requiring most urgent attention.

The question of the cost incurred in improving existing conditions and the way in which this can be met would appear to be of fundamental importance. It is hoped therefore, that in the discussion which is to follow, a plan can be formulated to implement some or all of the proposals that have been suggested.

In conclusion, the Author would like to thank all those who have so kindly helped by providing information which has been of such assistance to him in the preparation of this Paper.

DISCUSSION

Mr. J. H. Fraser in opening the discussion, said that the paper dealt with one of the most important subjects that could be presented to the Institution at the present time, and was an exhaustive review of questions that the signal engineer had to consider ; he congratulated the Author on its excellence. There had been revolutionary changes in road traffic in recent years, vehicles being faster and heavier, but wandering animals had virtually disappeared. He recalled the time when animals used to wander about the roads comparatively freely, and a good deal of level crossing protection was designed accordingly. Two major questions came to mind. Firstly, could an increase in effective protection be secured at level crossings by conversion from gates to barriers with lights, or by taking away the barrier and having lights alone ? Secondly, what could be done at the two-hundred or so occupation crossings where there was heavy traffic and a major disaster could occur if a heavy express train ran into a large road vehicle.

There was an important legal aspect to these matters, and no doubt signal engineers could reduce the cost of level crossing protection appreciably, if it were not for legal restrictions.

Mr. E. G. Brentnall said that it might not matter very much if there was one type of level crossing warning in the U.S.A., and other types in Canada, South Africa, and so on; but in the case of countries close together, as in Europe, with road vehicles running from one country into another, it would be very undesirable and would be confusing to road users. Recent discussion had taken place on the Continent in an attempt to standardise road crossing warning devices there, but it had proved to be a complicated matter owing to the different methods in different countries. In Germany, Denmark and Switzerland, they had stop signals for road traffic, without any " track free " signals. In Czecho-Slovakia and France they had stop signals and " out of order " signals ; in Italy, stop signals and " out of order " aspects ; and in Austria, Belgium and the Netherlands, stop signals and also " track free " signals. Naturally, no country wished to spend money on altering its own arrangements. An independent report had been made in an attempt to get the best results and it was interesting to examine some of the arguments. Stop aspects could be shown by one or two flashing lights, but the suggestion was to have one stop light on the side of the direction of traffic, which, on the Continent, was usually on the right, and for busy crossings to have another one on the left. With regard to the " track free " aspect—or, as some preferred to call it, the " pass " aspect—the general feeling was that some such aspect should be given. The economic side entered into it, because if there was a light for " track free " or " pass," it meant there was a light there for most of the time, and also during the time of no passing. Consequently, batteries would not be practicable and power supplies on the Continent were not always readily available. The recommendation was for either flashing aspects or small barriers fitted with reflectors and painted with a reflective colour and which, in their vertical position, would indicate " pass." It was thought to be desirable to show a " track free " aspect, because it was the logical counterpart of a " stop " aspect. Without a " pass " aspect, if the red light failed, road users might be misled. It was felt that there should be no " out of order " aspect, if the " stop " aspect should fail, as it was considered that it would be psychologically bad for road users to think that anything like that could fail. These references applied largely to crossings with no barriers at all. It was felt that if barriers were provided, there would be no need for the two red aspects, as the barriers would indicate that road vehicles should not pass. Also, no " pass " indication would be given, because the barrier in the air would mean that traffic could pass.

Colonel D. McMullen said that the subject was one in which the Inspecting Officers of the Ministry of Transport were particularly interested and vitally concerned.

He thought that a false impression might arise regarding the analysis of accidents at level crossings, the figure which the Author quoted of an annual average of 38 persons killed at level crossings in Great Britain for the last five years included the figure for pedestrians walking over crossings. The actual average number of passengers who were travelling in road vehicles, and killed, was only 13 during the last five years. Of those 13, 4 were killed at public level crossings with gates, 1 at a public level crossing without gates, and 8 at occupation level crossings. He agreed with the Author that comparisons with other countries were invidious, but, at the same time, few, if any, would disagree that level crossings in Great Britain were the safest in the world. The safety of those crossings was largely due to the original and rigid laws made by our forefathers, and also the requirements that have been made by the Ministry of Transport practically ever since the beginning of railways. He suggested, therefore, that any relaxation in the standard of protection, which might lessen their record, should be made very cautiously.

There were many public crossings in this country not protected by signals, and a number of those crossings had neither telephones, repeaters of the block bell, nor block indicators, and the security of the road traffic, and in fact, the rail traffic, passing over those crossings rested with the gatekeeper. He was glad to say that the number of such crossings was being reduced every year. There were also other crossings in this country, the gates of which did not close across the railway, but opened away from the railway. It was of interest to know that legal experts were not in accord as to the interpretation of certain sections of the 1845 Act ; hence the necessity, mentioned by the Author, of making quite certain that barriers or anything other than gates closing across the railway will be in accordance with the law.

There had been some unfortunate accidents of recent years, but generally speaking, the figures which he had quoted for public level crossings were not alarming. In the paper, mention was made that, at non-gated crossings, the road user should be forced to halt before crossing the line, but he thought that would be difficult to enforce, as the British public would most likely consider it to be infringing their established rights. Generally speaking, he did not think that the road users in Great Britain were as skilful drivers as those on the Continent. It had been said on good authority, that British road users were not as well disciplined as those in the United States. He considered that the question regarding public level crossings was not so much a safety problem as an economic one, and he was interested in the various suggestions put forward by the Author to solve it.

The paper described the lifting barriers at Warthill, which Mr. J. H. Fraser was instrumental in constructing and which he (Colonel McMullen) had been called on to inspect. It was a very good job, and he had no hesitation in recommending it, with certain modifications and without some of the ancillary features. Among other things, the revolving " stop " boards, which were floodlighted when facing the road, he considered unnecessary, and floodlighting, to the extent that was provided at Warthill, he also considered unnecessary; although these features might be necessary at some other crossings. One of the points made was that the construction was very heavy and he thought that could also be applied to gates protecting public level crossings. Speaking personally, he could see no objection to either gates or barriers being of considerably lighter construction than they had been up to now.

The British Transport Commission were seeking legislation in their Bill for the adoption of barriers as a substitution for level crossing gates, but it might be of interest to know—and it might be rather significant—that they had already had indications that that particular item in the Bill was to be opposed. The Author had pictured the signal engineer tied hand and foot by centuries' old legislation. But when it came to the substitution of lifting barriers for gates, was it really so ? Or could it not be that the high cost of some of the electrical equipment in these days was, to a considerable extent, responsible, leading to the retention of the manually operated gates for many years to come, notwithstanding the very increasing cost of labour.

So far as public level crossings were concerned, the Inspecting Officers appreciated the financial burden which was placed on British Railways, and they were ever willing to give sympathetic consideration to any scheme which might be put up to ease that burden, provided that it was based on sound safety principles.

Accommodation and occupation crossings were, to his mind, the main problem, and far more important problems than public level crossings, particularly those which had assumed public status, although they were not legally public level crossings. Now that mechanisation has replaced the horse, there was the potential danger of a serious accident occurring at such crossings. Experience had shown in the last few years that even a light motor car could derail a heavy express passenger engine. Fortunately, within the last five years' figures, no passengers in trains were killed. They would probably recollect, however, two serious accidents at level crossings which occurred at Wormley in 1924 and Hillgay in 1939, in which trains were wrecked and there was a considerable number of passenger casualties. There, he maintained, the problem was entirely financial ; the Railways' view is that the circumstances are not of their making. Unfortunately, there was no central fund in this country from which to draw in order to pay for additional security which all would like to see provided. The Road Fund is not available for such works. The suggestions which the Author made were not unlike many of those put forward by the British Transport Commission, which had been circulated to nearly all the interested parties in the United Kingdom. Opposition that had been received to those suggestions had been great. The whole problem was, therefore, fraught with difficulties. He wondered if British signal engineers could contrive to develop some exceedingly simple and cheap form of device which would give the road users at occupation and accommodation crossings a visual indication of the approach of a train. In olden times, people put their ear to the ground to hear whether horses' hooves were approaching. Could not the vibration which a train makes in the rails be used to give some visual indication that a train was approaching ? He thought that that particular suggestion might be impracticable, but he suggested that consideration should be given to the production of some device of that sort.

The Inspecting Officers would welcome proposals from British Railways for the experimental adoption or installation of automatically controlled lifting barriers at some of these particularly unpleasant occupation type of level crossings which were not manned, and he asked whether British Railways could not forget the financial difficulties, for the time being, and finance such an experiment themselves—without prejudice, of course, with regard to anything that might be done in the future.

Mr. D. R. Greig of the Automobile Association, said that road users in general felt very well satisfied with the measures taken in the United Kingdom to prevent accidents at level crossings. Their main complaint was the delay to road traffic, which all to frequently occurred, though it was appreciated that was due to safety reasons. Regarding advance warning of a level crossing, he thought that the road traffic warning sign was rather too small for present-day conditions. The " double bend " sign was a larger size than any other and he thought it more effective. Regarding the devices used at the crossings themselves, he emphasised the importance of simplicity and uniformity. He suggested that level crossings should be abolished from main traffic routes, wherever possible, but where they remained, there was a strong case for trying out a new system for reducing delays ; always providing it could be done without prejudice to public safety. When evolving such a system, they might be able to even improve on the very high standard of safety one had come to expect in the United Kingdom.

Mr. A. J. A. Hanhart of the Royal Automobile Club, thought that the accident record of the Railways in general was a most enviable one. If road users approached the degree of safety which the railways had achieved, they would be proud ; but unfortunately, this was not so. Accidents on level crossings were exceedingly small compared with accidents on other parts of the road, nevertheless, everything should be done to prevent them.

Many Americans considered the discipline on the British roads very much better than in their own country, and recently, visitors from Denmark commented on the politeness and courtesy of the British driver.

Money to be spent on protection should be spent in the right direction and to best advantage. The suggestion that the Road Fund might be used to overcome the financial difficulty was an excellent one from the railway point of view, but not from the road user's. Money for safety measures should be spent in a way which would save the most lives, and as the accident record for level crossings was good compared with that for the rest of the roads, it might be spent more advantageously on other parts of the road.

Mr. H. J. Guthrie agreed that a good many of the problems were legal ones. The 1845 Act required the gates to be across the public road, but at the discretion of the Ministry of Transport or relevant department, they might be left across the railway. He never could understand why discretionary powers were necessary ; it was a matter of common sense. With a narrow crossing and the next train in an hour or two, why open the gates twenty times ? However, it might be possible to have that altered legally. In the paper, it was stated that the railway companies were under no obligation to supply gates at all. The legal position was that the railway company must not harm anybody whilst crossing the track. There were no lamps on the gates in Ireland ; there was only one lamp on the crossing and that shone along the railway. It had been the practice, in the past, for the gates to be operated by a permanent way man and his family in exchange for the free tenancy of the crossing house. In the old days, there were only a few vehicles using the crossing, but now it was a 24-hour a day job, in most cases, and it became increasingly necessary to pay full-time gatekeepers. To his mind, the incentive for barriers was having some automatic means of operating the crossing, without the necessity of a crossing keeper. If that could be done economically, eliminating the high cost of staff, it would go a long way to meeting the railway problems.

In Ireland they had come to the conclusion that it was better to provide a telephone at every crossing, rather than protect it by signals ; and in recent years, most of their crossings had been fitted with a telephone connected to the nearest block cabin. It was an offence for anyone to put up signs on the roadway except the Highway Authority, so they could not have lights, even if they wished to have them.

He asked if there were any means of operating the automatically controlled crossing by batteries at places where there were no power supplies for many miles.

He was very interested in Colonel McMullen's reference to the possible introduction of legislation to permit barriers to be used in lieu of gates, because in Ireland they had had a similar recommendation made to them by some American experts.

Mr. N. Seymer, World Touring & Automobile Association, referred to the possibility of human error on the part of gatekeepers. It cost a good deal of money for a crossing that had to be manned for 24 hours a day and yet it did not provide complete safety. He mentioned figures which showed that manually operated gates for 24 hours had an accident quotient of 45, and were about twice as safe as completely unprotected crossings. Half barriers had a quotient of 14, or one-third of that of the manually operated gates. The figures seemed to indicate there would not be too much risk if automatic half barriers were installed at the most important crossings. That had been advocated at Geneva. The point of view of the road user was to reduce delay and, at the same time, provide greater economy for the railways. The German railway engineer was concerned with this problem and estimated that automatic half barrier installations paid for themselves in about four years, and afterwards effected substantial annual economies. He entirely agreed with Colonel McMullen that the problem could not be solved hurriedly, but thought that the figures justified some trials being made. It had been suggested that large-scale tests should be carried out internationally on 1,000 crossings throughout Europe, which might be equipped with half barriers, including crossings where accidents had occurred, and it would be interesting to know if Great Britain intended joining in those tests. Britain had a reputation on the Continent of keeping out of enterprises of that sort, which he considered was a pity.

Regarding batteries, the French Railways were not at all keen on a light which showed that the way was clear, because it would be difficult to operate by batteries; therefore, they proposed a semaphore arm to come down when the line was closed and it would also fall automatically if out of order. As that would require a motor to set it again, he could not see that it would be cheaper than a half barrier.

Mr. J. Runnett said that in the Argentine, particularly around Buenos Aires, the problem of level crossing was little less than fantastic. He knew of a power driven set of four gates being smashed as many as four times a week, on a throughfare carrying six lines of traffic. A bell was sounded but the traffic would carry on and delay trains. They had to pay for policemen to be stationed either side of the crossing and if they left their posts everything was in chaos.

Referring to the question of gates versus lifting barriers, he said they had barriers at the majority of the crossings, and he considered them faster, cheaper and easily repaired compared with gates. Motorists were more afraid of something coming down on them, or smashing their windscreens than of gates which they hit with their bumpers, sometimes in a rage.

With reference to the use of barrier curtains, they were necessary as a protection against animals, but in towns where it is prohibited to drive animals along the street they might be eliminated. This is done in Buenos Aires in 95 per cent of cases; curtains only being used at particularly difficult crossings. Curtains however, are not so effective for human beings where license rather than liberty is the rule. At one crossing where it was thought the problem had been solved by a curtain, football crowds used to force their way through or lift the curtain up bodily and with hundreds on the crossings, signals had to be thrown to danger at times. The problem was solved by covering the curtain with a heavy coating of black grease, and numbers of youths had a lesson with ruined suits. This method was cheap and adopted permanently. Curtains hang out into the roadway and cut down road space and are apt to catch such high vehicles as pantechnicons with disastrous results.

In regard to the lifting barrier at Warthill, he did not favour this type. If a steel tube of such strength were hit by a heavy road vehicle if might bend towards the track and though set in a trailing direction might smash the windows in a train. There is also the possibility of the whole barrier being brought down and the steel tube getting under the train with disastrous results.

He spoke in favour of the light wooden type of lifting barrier somewhat similar to the construction shown in fig. 12 and as used in the United States. These can be lowered quickly, offer little resistance in storm wind and if hit they fracture on the outside limb or on the end section. This generally causes the barrier to droop and fall away from the track or crack off altogether. They can be replaced quickly; a spare one can easily be housed in the open alongside the track. Another vital question is that of warning horse drawn and other vehicular traffic not possessing powerful headlights. Reflectors are useless in these cases and danger ensues where electric power lighting is not available.

He had given thought to a sign such as " 4 Tracks " lighted from the inside like a train indicator by an oil lamp, or in the case where powerful engine headlights are used, to pipe the light through perspex to the reflectors on the various signs facing the road user.

Mr. P. A. Langley (*in a written contribution*), said that the speed of road traffic had increased and, in addition to improving the road surface for such traffic, it was necessary to improve the alignment of the road. Years ago the tendency was to provide crossings at right angles to the railways, even when the road was at a sharp angle. Many mishaps had been caused and much damage had been done to gate equipment by heavy road vehicles and fast moving cars having to square themselves up to cross the railway. Today a main trunk road is 22-ft. wide. In addition, some authorities require a margin of 5-ft. each side for overhanging loads, making a total width inside the gates of 32-ft. The tendency is, therefore, for larger gates to be provided and, at skew crossings, it is difficult to prevent them becoming unwieldy.

The Author had not mentioned the Road and Rail Traffic Act of 1933 which gave the Ministry of Transport authority to permit, in certain circumstances, the normal position of gates to be across the railway instead of closed to the roadway. This was brought about largely by force of circumstances, as the road traffic was so frequent that it was impossible for the attendant to keep the gates closed to the road. There are still some crossings where the gates do not completely fence the railway when open to the road and either cattle grids or additional gates have to be provided before Ministry of Transport sanction can be obtained to alter the normal position of the gates.

The provision of overbridges in lieu of crossings and the modernisation of other crossings shows that the railways are aware of the need for improvement. It is not correct to say that they bear the full costs. The Local Authority and the Ministry of Transport contribute towards the cost of installation and maintenance of work in which they are interested.

The Automobile Association provide, fix and maintain, free of cost, red reflectors, also road diversion signs for closing or partial closing.

With reference to figure (1), the white sidelights shown on the gate lamps are, presumably, to enable engine drivers to identify crossings at night-time where no signalling exists. Where stop signals are provided, white sidelights on gate lamps are objectionable, as they can cause confusion, especially as the revolving gear would not be provided.

Mr. L. J. M. Knotts (*in a written communication*), said that the paper was a valuable addition to the Proceedings, particularly in view of the information which it contains on practices in so many countries. The Author stated it would be invidious to compare the accident statistics between the United Kingdom and the United States and he agreed that the difference in conditions must be taken fully into account. At the same time from figures produced it was possible to show that the average number of killed per annum, in very round figures, was between 6 and 7 per 1,000 crossings and 18 injured per 1,000 crossings in the United States, and between 1 and 2 per annum killed and injured per 1,000 crossings in Britain (including the 22,600 occupation crossings). This shows that the accident rate of both countries is remarkably low and does not appear to be at all alarming. It would have been interesting to know what proportion of the total accidents in the United States occurred at the 190,000 crossings which have no physical protection. There are two major objections to wheel-worked gates from the engineering point of view. Firstly, there is a good deal of apparatus under the roadway which is difficult to install and maintain and secondly it is necessarily a cumbersome arrangement which it is not at all easy to make smooth in operation. The work of the signalman under modern traffic conditions especially at large and skew crossings is very onerous and under electrification with increased train services the problem is much aggravated. Power operation can help in these cases to ease manual labour but power operation is not so flexible and there is more danger to vehicular and pedestrian traffic since there are individuals who will try to beat the gates. The operator who is manually working the gates can maintain the feel of them all the time but with " push-button " control there is a time lag in making any change, during which an accident can occur.

It is popularly supposed that power operation would speed up matters at level crossings. This is not true as there is a limit to the speed at which gates having considerable inertia can be moved, It is not the actual time for the gates to move which causes the principal delay to road traffic. If traffic lights are provided there is more delay to road traffic for obvious reasons, both with gates and barriers. There would be occasions at certain crossings where the signalman might open and reclose gates under power working for trains closely timed in opposite directions which he might not be willing to do under manual operation, but this is hardly likely to make any material difference in view of the rules laid down and which are essential for safety.

It would appear that barriers provide a solution to some of the objections which arise with gated crossings but we shall always need road colour light signals in association with them, and this being so one could not expect any amelioration of the problem of delay at level crossings. Automatic operation would of course greatly increase costs and would not be practicable in many cases. As presumably any conversion to barrier working would begin with the more important places the question of power supply might not present difficulty, but there are a large number of places where there is no power supply readily available at the present time.

Mr. Knotts did not think that the skirting on barriers could be eliminated because of children and animals, especially in densely populated centres.

One of the problems of the present day is the movement of heavy mechanical vehicles over occupation crossings. The Author advocates a trial with barriers at selected crossings but there is much to be taken into consideration from legal, financial, operating and engineering points of view. With a train travelling at 80 m.p.h. or more, the warning and barrier operation would have to start while the train was two or three miles away, but this may be in a portion of line where there are junctions, and other trains which will be diverted will operate the warning. Again, other trains only travelling at 30 or 40 m.p.h. or even less towards the crossing would possibly cause a man at that point to think there had been a failure owing to the time taken for the train to appear. The same difficulty occurs with all trains approaching in opposite directions simultaneously and it seems that telephone communication would have to be provided in any case. Proving of lights and barrier operation would be required to give maximum safety but a manned box might be ten miles away at certain times when boxes were switched out. With automatic operation it seems there is a danger of a man with a vehicle being shut in on the crossing and there is a possibility that there might be more accidents instead of less with automatic barriers at occupation crossings; also, gates would still be needed at certain localities to keep cattle from the crossings.

The **Author,** in reply, said that he was very pleased to note from Mr. Brentnall's remarks that some attempt at standardisation was being made in Europe.

In reply to Colonel McMullen, he appreciated that the number of persons killed mentioned in the paper were not all in cars, and thanked him for pointing out what might have caused a wrong impression. So far as interlocking was concerned, he had not realised how many crossings were interlocked with the signals. It had seemed to him that if the red aspect could be seen from a reasonable distance, no signalling would be provided, but if visibility was such, a distant signal would be added, and if there was a gradient, there would also be a stop signal.

He was pleased to note that Colonel McMullen agreed that "halt" signs would be beneficial at ungated public crossings although he was sorry that he did not think they could be introduced. He was also pleased to hear that barriers could, in Colonel McMullen's opinion, be of lighter construction. Those at Warthill, in actual fact, weighed just over three-quarters of a ton each. It would be possible to make gates and barriers much lighter.

It was true that power operated barriers might be more expensive, in first cost, than mechanical gates, but there should be considerable saving in maintenance ; and if automatic barriers could be adopted, there would be even greater saving in man-power and wages.

So far as occupation crossings were concerned, he would be interested to know what the B.T.C. proposals were, and was sorry to learn that they were being opposed in certain quarters. Certainly, it would be very difficult to find a cheap solution.

If the railways could be freed of liability for accidents caused by failure of any controlled protection devices they provided at occupation crossings, it would be one step in the right direction ; but he did not think that any signal engineer would recommend anything liable to failure, as they felt themselves morally responsible for such failures.

Replying to Mr. Guthrie, he knew of no primary battery scheme to suit his requirements.

The **Author** thanked Mr. Greig, Mr. Hanhart, Mr. Seymer and Mr. Runnett for their contribution to the discussion, to which he had listened with great interest.

The **President** moved a very cordial vote of thanks to the Author for his extremely interesting paper, and this was carried with acclamation.

The **President** then announced that the next Technical Meeting would be held on February 17th, when Mr. J. F. H. Tyler would read a paper on " Some Signalling Developments on the Western Region, 1947-53."

APPENDIX 'A.'

(ALL QUANTITIES APPROXIMATE)

	Eire	U.S.A.	Canadian National	Canadian Pacific	Argentine	Chile	Uruguay	S. Africa	Rhodesia	Egypt	Turkey	Israel	Italy	France	Denmark	Holland	Sweden	Swiss	Belgium	India	Pakistan	Burma	Malaya	New South Wales	Victoria	South Australia	Western Australia	Queensland	Commonwealth	Tasmania	New Zealand
Total Number of Crossings	940	227,415	15,962	13,500	40,000	600	1,298	4,800	300	1,357	5,200	289	17,264	36,000	12,500	7,000	38,600	4,115	4,850			1,500	276	5-6,000	3,670	1,730	3,775	5,006	239	781	2,400
Protected by—																															
(*a*) Manually Attended Gates	572				50-100		2			21			5,126		953	81	330				20%	1,500	75		280	7	5	1,201			
(*b*) Unattended Gates						100		300					5,410		9,469		?	874			70%		6								
(*c*) Manually Attended Barriers		5,014	118	65	3-4,000	360	136	35		528	300	33	5,308	24,000		988	2,470	1,721	2,100	103	10%		27	34	1	5	1	2			
(*d*) Auto. Barriers				10	2	24	6					1			2	6	5									3					
(*e*) Auto. Audible & Visual Warning		15,031	705	455	100-200		44	2		22				200	990	95	880	87	375					6	81	90	3	8		4	
(*f*) Auto. Audible Warning		2,152		5	200-300		57	1									185									24			1		202
(*g*) Auto. Visual Warning		11,169						98	15						900		60							3		1	33	8	11	118	
(*h*) Fixed Warning Signs	Balance	190,733	Balance	Balance	Balance	Balance	Balance	Balance	Balance	199	Balance	Balance		Balance		2,059	1,970	Balance	Balance				17	Balance	Balance	Balance	3,733	Balance	227	Balance	
(*j*) Watchmen		3,316	31	10						414			1,420																		Balance
(*k*) Zig-Zag (Pedestrians only)										173																					

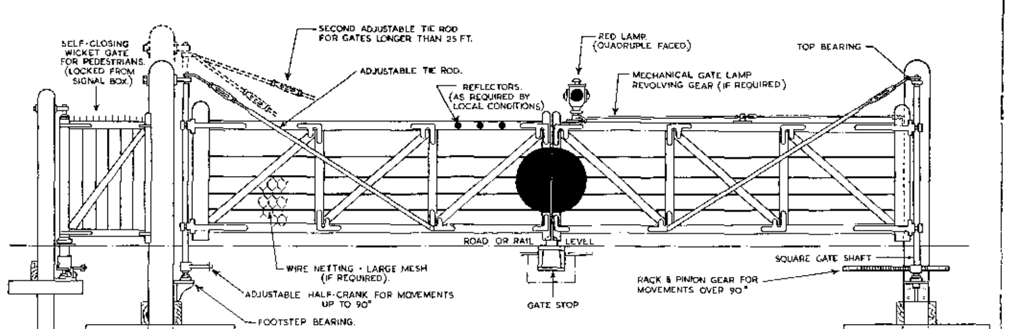


FIG. I.

TYPICAL PUBLIC ROAD LEVEL-CROSSING GATES. AS INSTALLED ON BRITISH RAILWAYS.

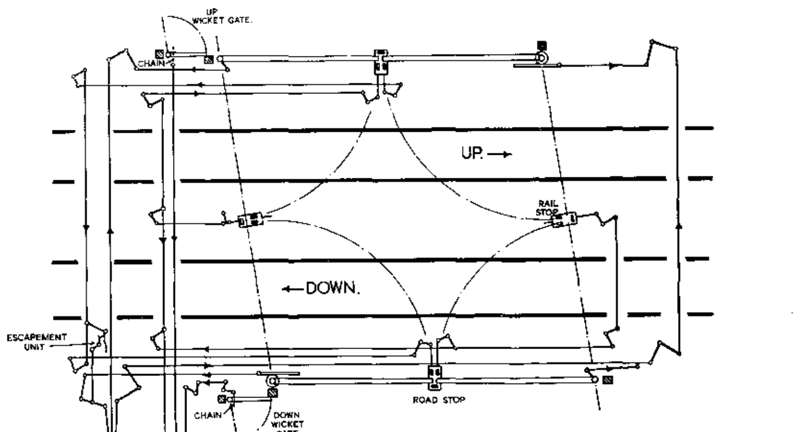


FIG. 2.

TYPICAL LEVEL-CROSSING GROUND CONNECTIONS. AS INSTALLED ON BRITISH RAILWAYS.

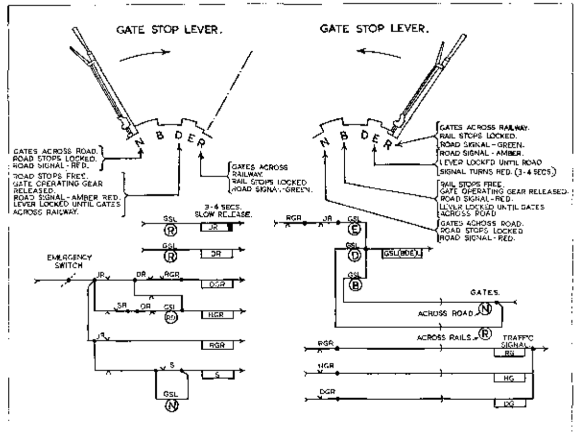


FIG. 3.

TYPICAL CIRCUIT ARRANGEMENT FOR LEVEL-CROSSING ROAD TRAFFIC SIGNALS.

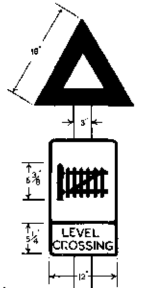


FIG. 4A.

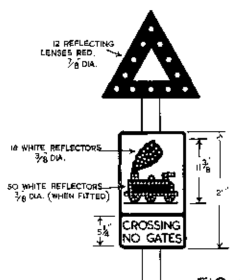


FIG. 4B.

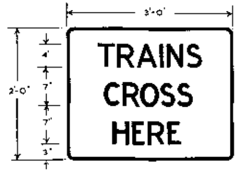


FIG. 4C.

ROAD WARNING SIGNS AS USED IN UNITED KINGDOM.

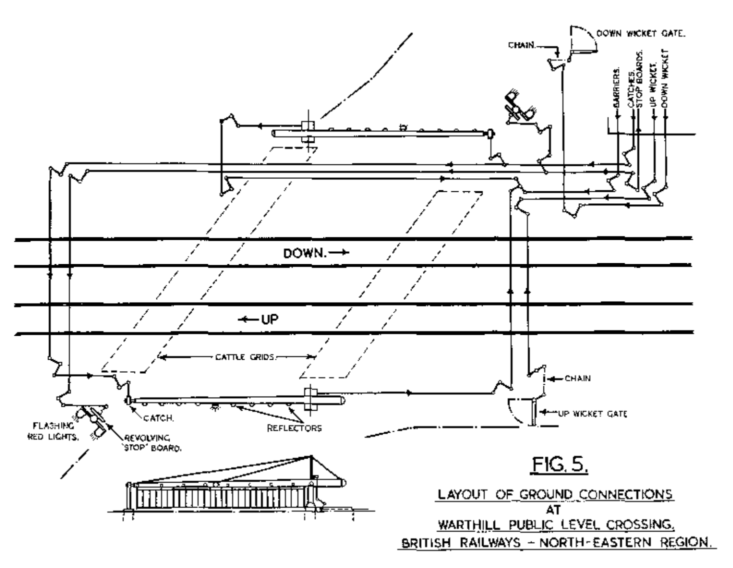


FIG. 5.
LAYOUT OF GROUND CONNECTIONS
AT
WARTHILL PUBLIC LEVEL CROSSING,
BRITISH RAILWAYS - NORTH-EASTERN REGION.

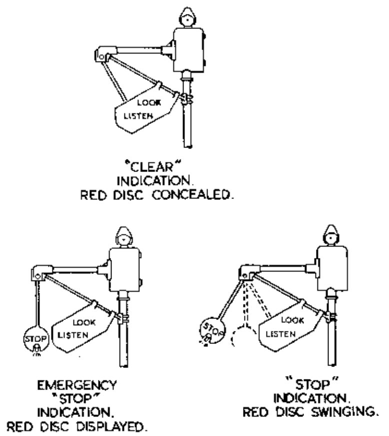


FIG. 8.
AUTOMATIC FLAGMAN OR WIG-WAG SIGNAL
AS USED IN
UNITED STATES OF AMERICA.

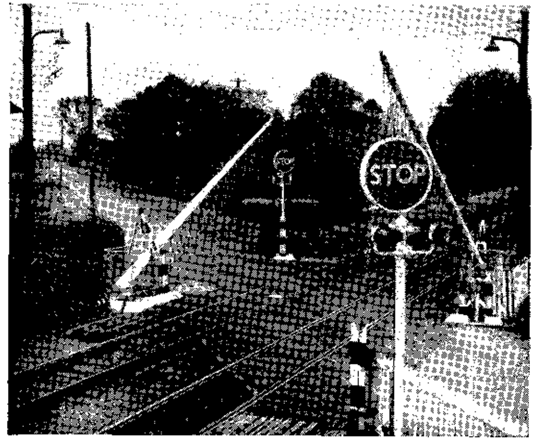


Fig. 6. Warthill Public Level Crossing, British Rlys., N.E. Region

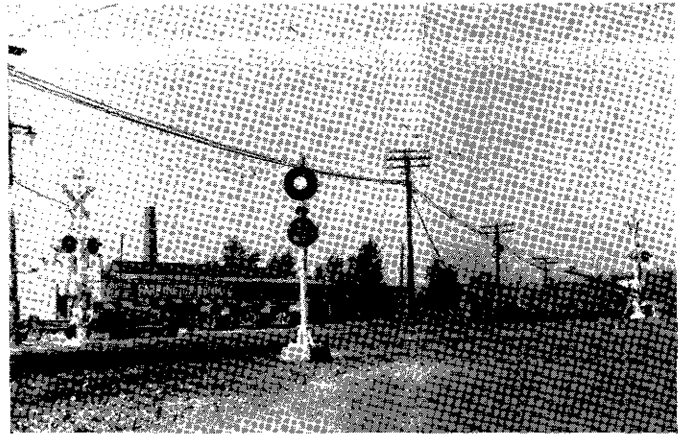


Fig. 7. Typical Installation of Level Crossing Protection Equipment in United States of America

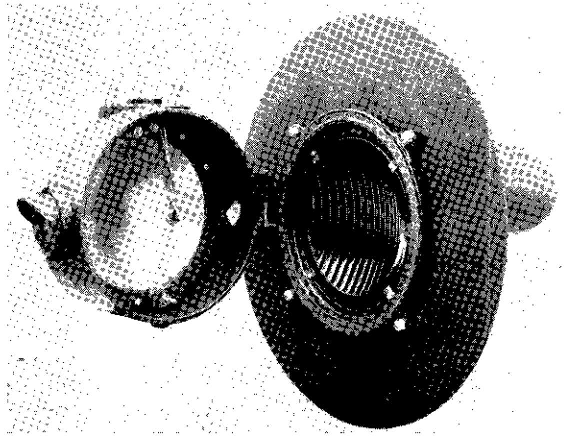


Fig. 9. Typical Light Unit as used in United States of America

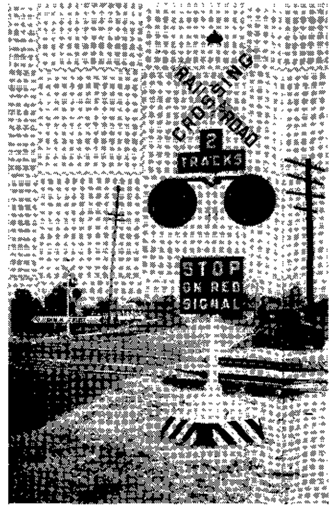


Fig. 10.
Typical Flashing Light Signal Assembly as used in United States of America

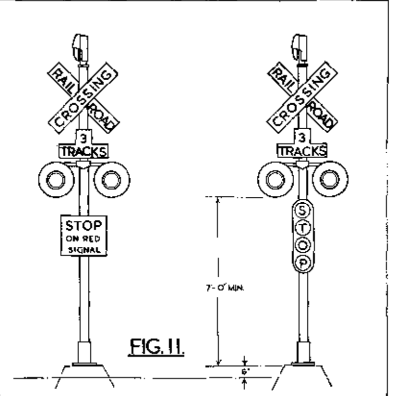


FIG. 11.

AUTOMATIC WARNING SIGNALS (FLASHING LIGHT TYPE) AS INSTALLED IN U.S.A.

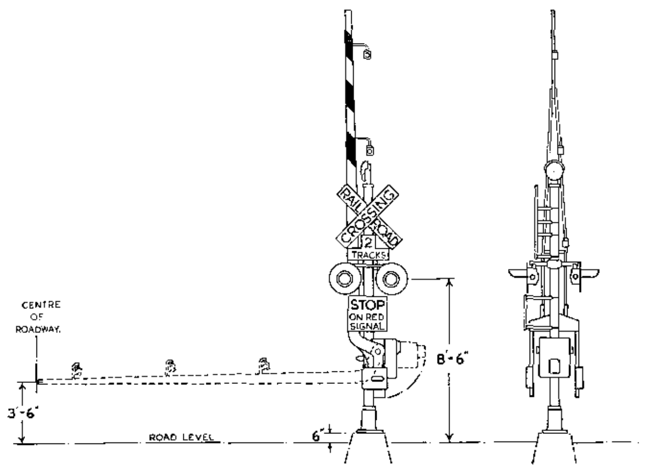


FIG. 13.

AUTOMATIC BARRIERS & FLASHING LIGHTS AS INSTALLED IN U.S.A.

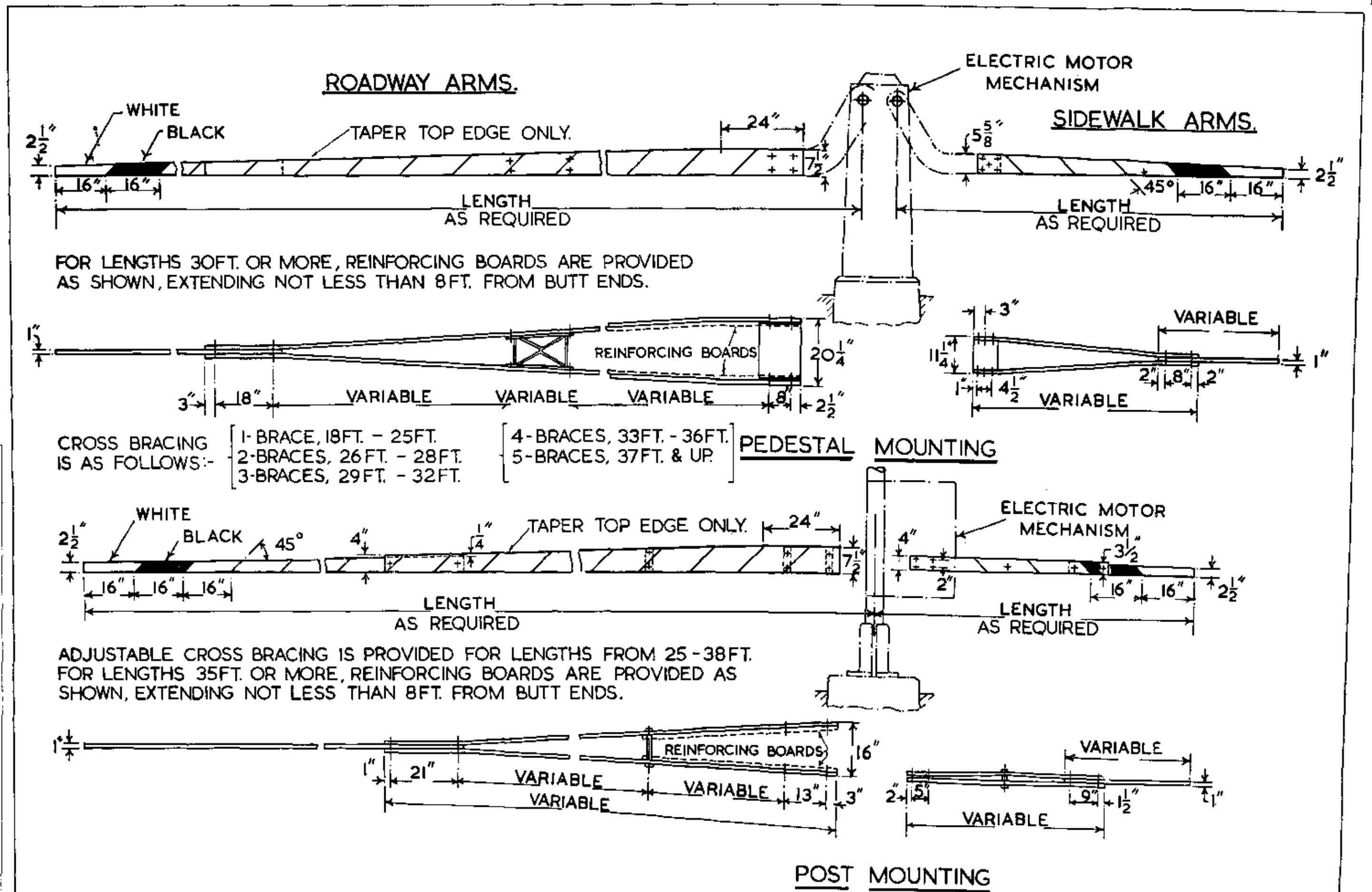
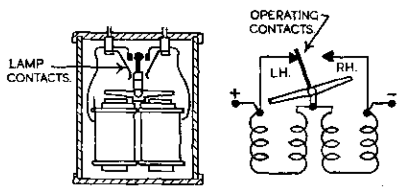


FIG. 12.

BARRIER ARMS AS USED IN THE U.S.A.

(LUMBER IS OF ONE INCH SELECT WHITE PINE OR EQUIVALENT, DRESSED FOUR SIDES)



D.C. FLASHER RELAY.

FIG 14.

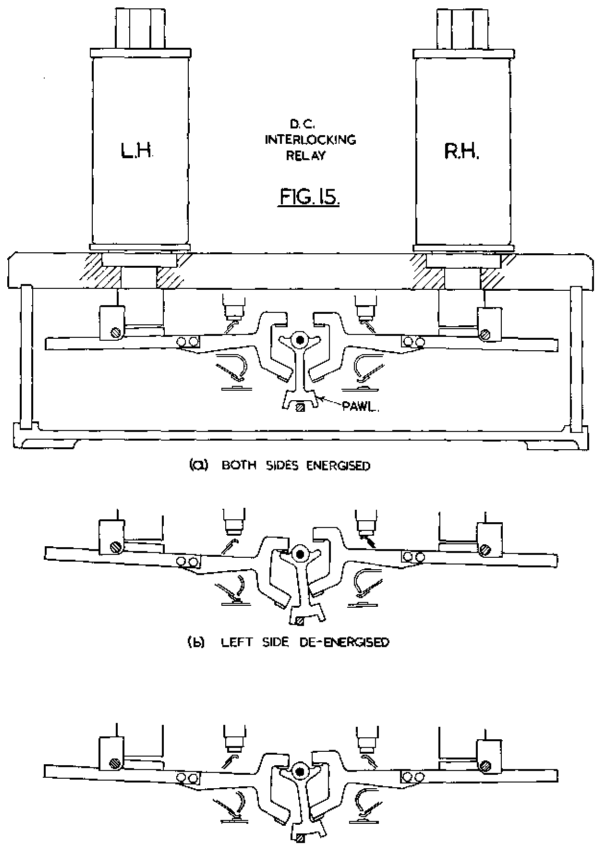
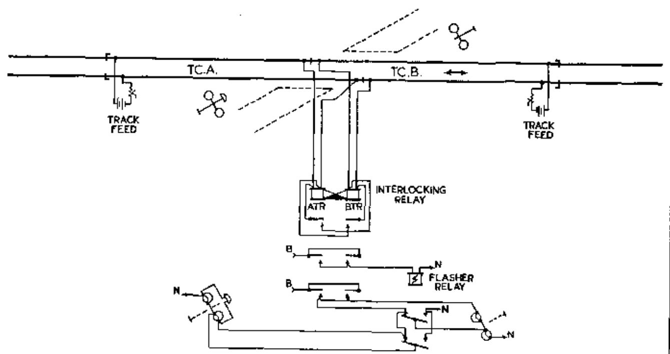


FIG. 15.

(a) BOTH SIDES ENERGISED

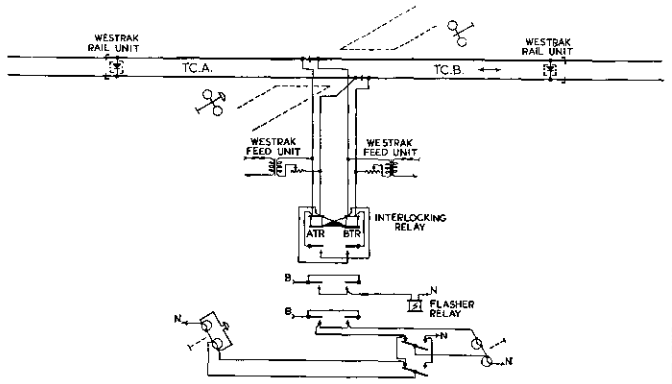
(b) LEFT SIDE DE-ENERGISED

(c) BOTH SIDES DE-ENERGISED



TYPICAL CIRCUIT ARRANGEMENTS
FOR
LEVEL CROSSING ON SINGLE LINES USING TRACK CIRCUITS.

FIG. 16.



TYPICAL CIRCUIT ARRANGEMENTS
FOR
LEVEL CROSSING ON SINGLE LINES
USING
COMBINED 'WESTRAK' AND INTERLOCKING RELAY.

FIG. 17.

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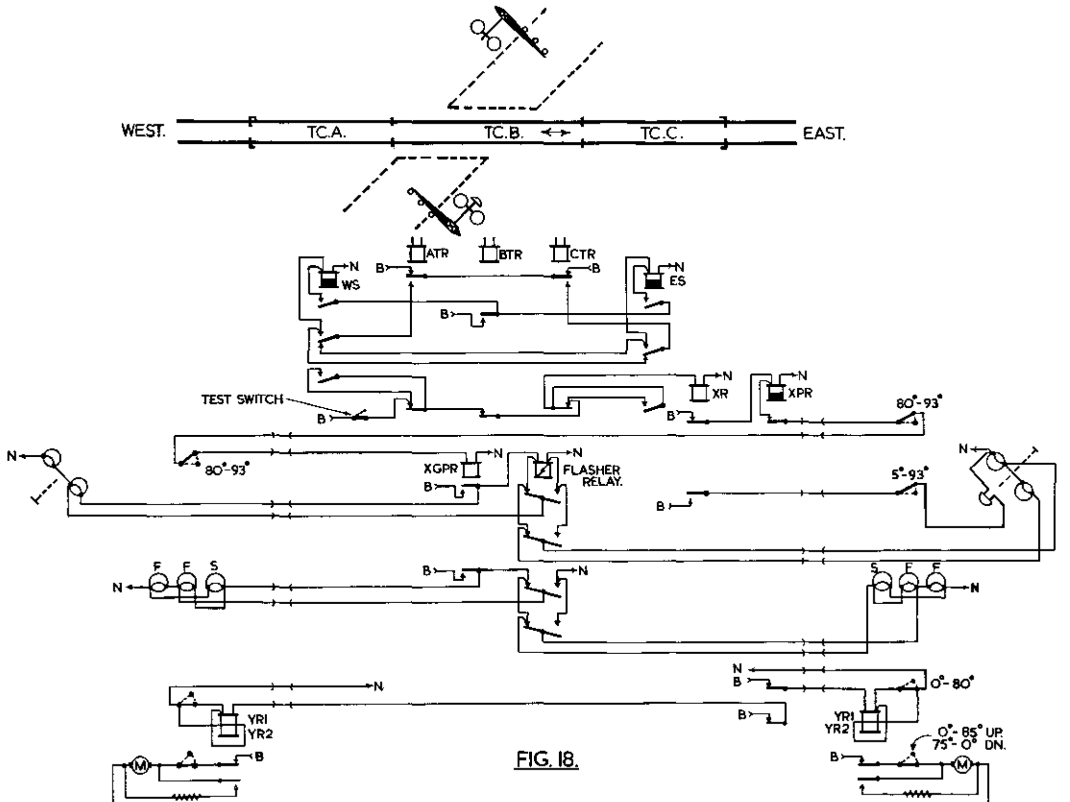


FIG. 18.

TYPICAL CIRCUIT ARRANGEMENTS
FOR
LEVEL CROSSING WITH AUTOMATIC FLASHING LIGHTS & BARRIERS ON SINGLE LINES USING TRACK CIRCUITS.

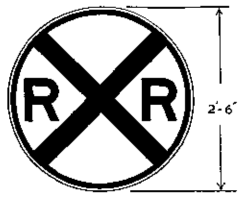
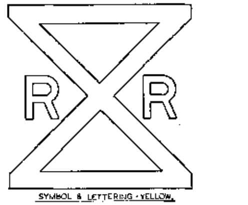


FIG. 19A.

BACKGROUND - YELLOW - BORDER, SYMBOL & LETTERING - BLACK.



SYMBOL & LETTERING - YELLOW.

FIG. 19B.

ROADWAY ADVANCE
WARNING SIGN.
AS INSTALLED IN U.S.A.

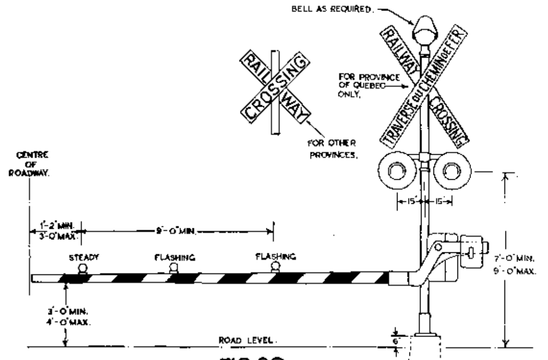


FIG. 20.

AUTOMATIC BARRIERS & FLASHING LIGHTS
AS INSTALLED ON
CANADIAN RAILWAYS.

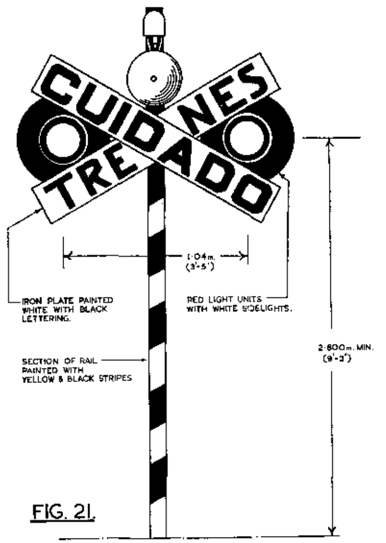


FIG. 21.

AUTOMATIC WARNING SIGNALS
AS INSTALLED ON
URUGUAYAN STATE RAILWAYS.

Proceedings 1954
Inset Sheet No. 7

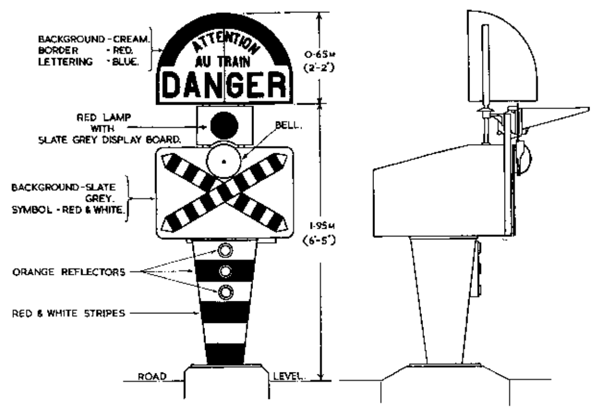
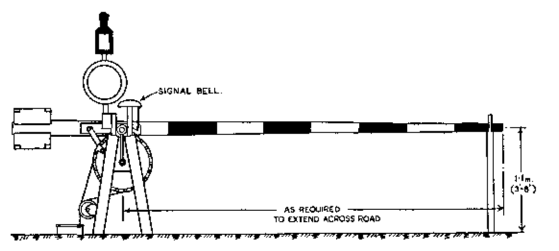


FIG. 22.

AUTOMATIC WARNING SIGNALS.
AS INSTALLED ON
FRENCH NATIONAL RAILWAYS.



MECHANICALLY OPERATED BARRIER
AS INSTALLED ON
SWEDISH STATE RAILWAYS.

FIG. 23.

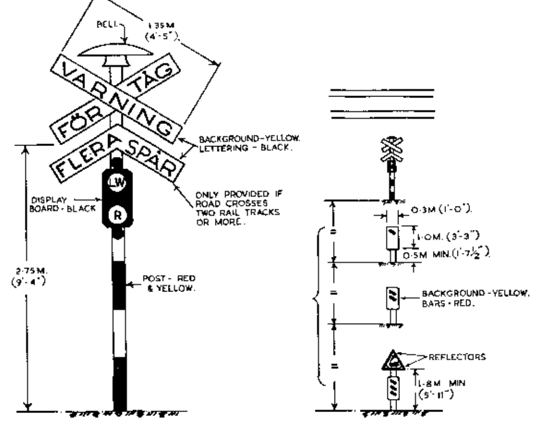
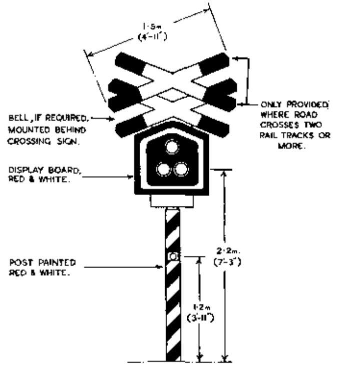


FIG. 24A. FIG. 24B.

AUTOMATIC WARNING SIGNALS
AS INSTALLED ON
SWEDISH STATE RAILWAYS



AUTOMATIC WARNING SIGNALS
AS INSTALLED ON
NETHERLANDS STATE RAILWAYS.

FIG. 25.

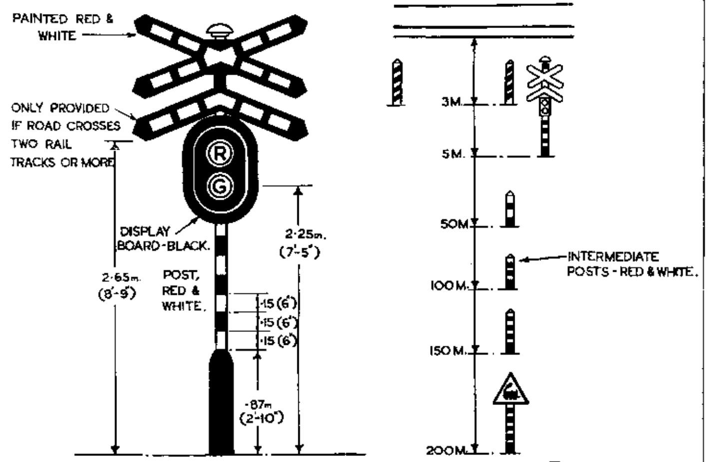


FIG. 26A. FIG. 26B.

AUTOMATIC WARNING SIGNALS
AS INSTALLED ON
BELGIUM NATIONAL RAILWAYS.

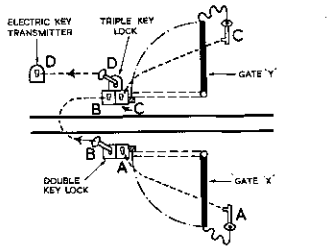


FIG. 27.

LEVEL CROSSING ARRANGEMENTS
AS INSTALLED ON
BURMESE RAILWAYS

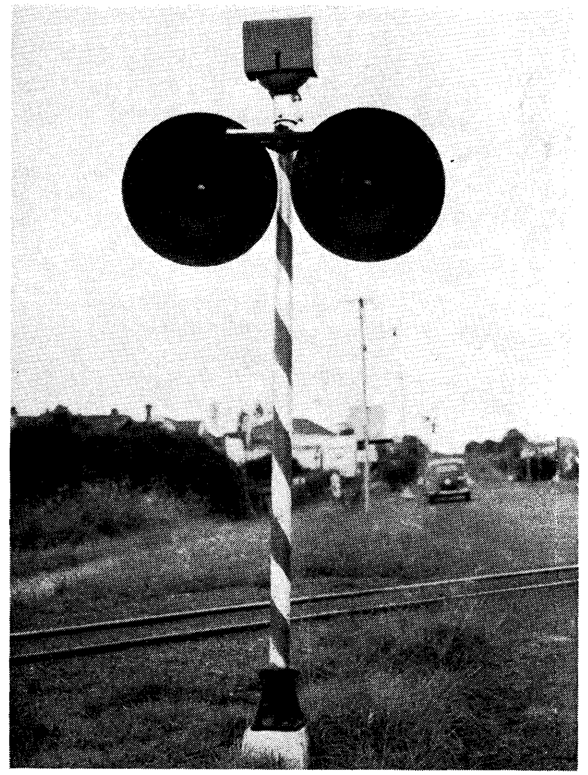


Fig. 28. Typical Flashing Light Signals
as used on New Zealand Government Rlys.

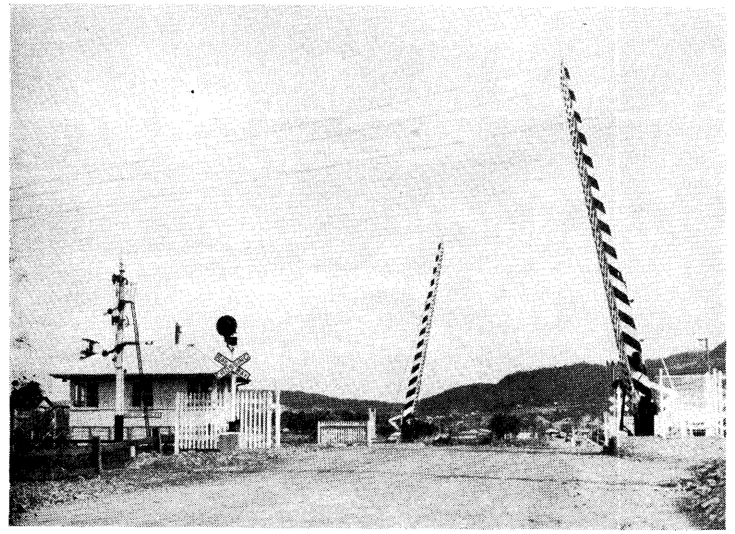


Fig. 29. Mechanical Barrier Installation, Mt. Keira, New South Wales Rlys.

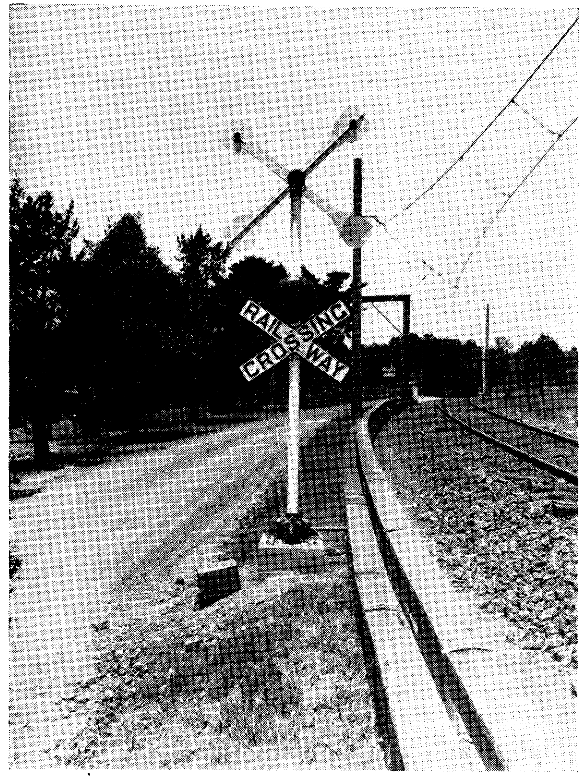


Fig. 30. Pearson Level Crossing Warning Signal
as installed on New South Wales Railways