Joint Meeting with the Institute of Transport

HELD AT

The Institution of Electrical Engineers,

Monday, 14th March, 1932.

The President of the Institute of Transport (Mr. FRANK PICK) in the Chair.

(*From the April* 1932 *Journal of the Institute of Transport*)

After some introductory remarks (see page 102) the Chairman called upon Mr. A. F. Bound to read his paper.

Railway Colour Light Signalling in Relation to Manual Block and Multiple Aspect Signals.

By A. F. BOUND (Past President).

(*Diagrams—Inset Sheets Nos.* 1-6).

One of the most pressing needs in the modern signalling world appears to be some greater co-ordination in the development of colour light signals and the various aspects formed by them, so that the indications may be the same whenever and wherever they are met.

A striking feature of American railways noted during a recent visit, was the extraordinary development in the use of such signals. Practically the whole of these are installed on the multiple-aspect principle, and not, as some railways are using them in this country, in substitution of the aspects conveyed by ordinary controlled manual semaphores, which are at variance with multiple aspects and will undoubtedly lead to confusion if the practice is allowed to extend.

In the United States, the arrangement of aspects is by no means uniform and, attached as an appendix A. will be found diagrams representative of the best American signalling development.

The chief features which emerge are :

(a) the use of marker lights,

(b) the arrangement of aspects so as to convey " speed " signalling.

(c) the almost universal use of " approach " lighting in automatic territory.

The study given to colour light signals and signalling over the past decade has resulted in the production of highly efficient units, both from the point of view of luminous intensity from a small wattage and also from that of distinctive hues.

A recent development which is sweeping through America is the re-designed " searchlight " or S.A. signal. This embodies the use of a vane or miniature spectacle carrying the three colours, red, green, and yellow, inside the body of the signal, operating on the principle of a polarised relay, the hue being given by the interposition of the required colour screen near the focal point of the lens combination ; this arrangement absolutely prevents any possibility of a false phantom indication by extraneous light, and permits the use of a reflector system whereby a beam c.p. up to 50,000 can be obtained.

There is no doubt that the colour light signal is the signal of the future and will gradually supersede the semaphore. Experience has already demonstrated that given proper siting with the lamp(s) about level with the driver's eye, fogging difficulties will largely be overcome, and, further, the advent of the searchlight signal capable of giving a high c.p. beam with a current consumption as low as 3 watts, used in combination with " approach " lighting, makes possible their individual use by battery operation where power supplies would at present be available only at prohibitive cost.

It therefore becomes more than ever necessary to review the whole situation and study the application of colour light signals and consequent aspects, in relation to the various types of signalling in use to-day, and the purpose of this paper is to do this and to suggest the lines along which colour light signalling should be developed in this country.

In doing this one important proviso must be borne in mind, namely, quoting Mr. Rudd of the Pennsylvania Railroad :— " That a given signal aspect must transmit the same information at all times, at all places and under all conditions, so that a driver will know instantly what it means and whether or not

it is properly displayed." With the introduction of a new form of signalling, uniformity of aspects should be made fundamental and any deviation therefrom should carefully be avoided.

In order to see how matters stand and where they are leading, a brief historical survey is desirable.

Ten years ago, apart from the "tube" railways, the only colour light signalling in use was that on the Liverpool Overhead Railway.

The only examples of multiple aspect signalling were three-position upper quadrant semaphore installations on the :—

G.W.R.,—Ealing and Shepherds Bush Railway.

G.C.R.,—Keadby Bridge—8 signals.

G.N.R.,—King's Cross—3 signals.

S.E. & C.R.,—Victoria Station, London.

In none of these was there any special feature beyond the three-aspect principle whereby each signal was a repeater of the one next ahead and, as the one installation only was in use on each company's railway, there was no risk of confusion with the ordinary signalling.

The first three-aspect colour light installation was put in on the Great Central Railway in 1923 between Marylebone and Neasden just prior to the opening of the British Empire Exhibition. Since that date progress has been fairly rapid, especially on the Southern and Metropolitan Railways (the former using this type throughout its suburban electrification), four aspects being introduced for the first time in this country, based on the recommendation of the Committee set up by the Institution of Railway Signal Engineers in 1922, whose report was issued in 1924.

Another recent installation of four-aspect colour light signalling was that installed by the London Midland and Scottish Railway at Manchester in 1928.

Numerous other examples are in course of installation or have recently been completed on the four grouped companies as well as on the Metropolitan Railway; colour light signalling may therefore be regarded as accepted practice in this country and well beyond the experimental stage.

Coincident with the above innovations, a number of railways started using colour light signals in substitution for semaphores, in isolated cases where bad sighting facilities and difficulties in fixing made such signals preferable to the usual oil-lighted

semaphore, and in doing this the light aspects of the displaced semaphores were usually perpetuated.

Reference has been made to the report of the Committee on Three-position Signalling set up by the Institution of Railway Signal Engineers, of which Committee I had the honour to be Chairman. It would be seen by the brief historical reference already made, that in the period 1922/24, during which the report was under consideration, there was very little actual experience to guide the members of the Committee. Whilst the report fulfilled a very useful purpose at the time, formulating a definite pronouncement on a subject about which very hazy notions were then generally prevalent, the time has now arrived to review the whole subject, and recast ideas in view of the experience gained and the progress made in the design and application of colour light signals, both in this country and in America.

What is the problem? It is the application of colour light signals to

(*a*) Manual block signalling using
  (i) electric lamps in lieu of oil lamps,
  (ii) colour light units, electrically controlled.
(*b*) Two-aspect signalling (automatic).
(*c*) Three-aspect signalling (automatic or controlled).
(*d*) Four-aspect signalling (automatic or controlled).
(*e*) Any further extension that may be found necessary.

For the purpose of this paper the term manual block signalling is intended to refer to signals of the semaphore type, lighted by oil or gas, and manually worked by mechanical means in a system of operation whereby the space interval is made effective by block telegraph instruments operating between adjacent signal cabins.

In dealing with this subject it is proposed to take as a basis the report of the Committee already referred to; and to set out the pros and cons of the various recommendations.

The terms of reference to that Committee are attached to this paper as Appendix B.

The report established a distinction between the terms "aspect" and "position," and this should be standard nomenclature for the future, any system involving more than the two aspects R and G being referred to as "multiple aspect signalling."

The message conveyed by a given aspect was also designated as the "indication," *i.e.*, any signal displaying the "caution" indication, and this word also should be standardised for the future in this connection.

The Committee laid down that the indications to be given by a three-aspect system should be :

Red light—Stop.

Yellow light—Caution—be prepared to stop at next signal.

Green light—Proceed, all right.

Experience has shown that these colours and interpretations can be accepted as the values on which a colour light system should be based to meet general conditions, now that the yellow light is the standard "on" colour for distant signals, subject to certain comments in the case of green as referred to later.

The following very important reference was made :

> "The point arises whether three-aspect signalling is to be regarded as a system for the saving of certain arms and lights and developed as such, or should it be regarded as a system the main function of which is to facilitate traffic working. Your Committee is of the opinion that the latter is the only view to be taken, the former being a subordinate consideration which should only be taken into account providing clearness of aspect is not thereby sacrificed."

Unfortunately, from want of experience, the Committee failed to look far enough ahead properly to give effect to this opinion.

A fourth aspect which they recommended and which has been adopted widely was :—

Attention—run at medium speed,

to be given by the aspect Y/Y.

This is acceptable so far as the aspect is concerned, but the interpretation "run at medium speed" requires further consideration.

Having provisionally accepted these four basic indications, it is proposed to consider first their application under the headings A to D already referred to and for this purpose "green" and its interpretation will be taken first.

The Committee gave this as "proceed—all right."

In a multiple-aspect system, including as it does a yellow cautionary aspect, the indication implied by the green light is that the next signal ahead is "off," displaying either a "proceed" or a "cautionary" aspect, and a driver is thereby encouraged to run at speed, confident that he will subsequently encounter

a "cautionary" signal placed sufficiently far out from any "stop" signal to enable him to pull up easily and confidently at whatever speed he may be travelling. This is commendable and should be in no way impaired.

When colour lights are applied to manual semaphore signalling the following problem has to be faced :—

In a distant signal, green means "proceed—all right" and tells a driver that not only the next signal is "off" but that often several other successive signals (including the starter, if provided), are "off" so that virtually it means "line clear to clearance point of next cabin in advance."

When the home signal is considered, it is found that green has two meanings.

If the distant signal is passed in the "off" position, green in the home signal confirms the indication conveyed by the former. If, however, the distant signal is passed at danger, then by rule 42 the danger signal must also be exhibited at the home signal until green is shown under the provisions of rule 40 (a). Should the starting signal still be at danger, the meaning is entirely different, the indication being "proceed at slow speed, prepared to stop at next signal."

At the home signal there is sometimes found yet a third interpretation of green, although it is only given under a red, forming the combination R/G. This refers to the calling-on signal, the indication of which is (a) that the line between the signal and the next stop signal (or buffer stop, when there is no stop signal in advance) is occupied, or, (b) that the driver is required to stop for instructions at the signal box ahead.

Taking the starting signal, again there are two conditions attached to the green aspect—(a) proceed under full line clear acceptance, (b) proceed under rule 5 acceptance. The relative rule governing this is 45 (c).

It will thus be seen that with manual block signalling there are no less that five different indications given by a green light aspect. Whilst to-day no confusion exists between the indications conveyed in multiple-aspect colour light and manual block signalling due to the comparative inferiority of the oil-lamps used in the latter signals, it is easy to appreciate that with a levelling up of the lighting, by substituting colour light signals

in lieu of semaphore signals and retaining the aspects of the latter, confusion would arise in the event of any considerable extension of the two systems.

A misleading sequence which would be possible is shown by diagram 1, appendix E, in which the top line represents correct multiple-aspect practice, and the bottom, the possibilities of the application of colour light signals to manual semaphore signalling (third line).

As previously explained, rules 42 and 40 (a) should obviate this contingency but cases frequently occur where they are not carried out. In fact, certain railways in busy suburban areas give definite exemption for trains stopping at stations, to facilitate working into the platforms, while others put up with the inconvenience and delay.

Turning now to the simplest form of colour light signalling, each signal displays two aspects, *viz.*, stop—proceed, and therefore the green or "proceed" aspect can only mean "proceed, line clear to next signal."

As a driver is given no indication, beyond that afforded by his vision, whether the next signal is "on" or "off," it is obvious that speed can be maintained only if he can see the next signal ahead, at least at braking distance from it. Therefore, to meet conditions in foggy weather when visibility is low, it becomes necessary to reinforce such a system, when used on surface lines, with "fog repeaters" placed at braking distance from each "stop" signal.

As such fog repeaters can be regarded as in substitution of the cautionary aspect of a three-aspect system, there does not appear to be any economy in indication units over a three-aspect signal system; it is therefore proposed that the use of two-aspect signals be confined to "tube" and other underground railways which are not subject to fog, and where signalling conditions are uniform and localized. If the proposal is accepted this particular aspect can further be disregarded.

Before attempting to decide the future application of colour light signalling to manual block signalling, it is perhaps desirable to try and define exactly what a green light aspect means.

It is well known that no signals are required on a line worked by one engine in steam, thus pointing to the fact that signals are "protective" in their function, and the essential aspects are "stop" and "caution."

In the early days of signalling, when trains were worked on the " time " as distinct from the " space " interval, semaphores, after a predetermined time, were lowered to a vertical position, out of sight inside a slot in the post ; the inference was that where no signal was displayed, the line was clear. This practice was afterwards altered as it was subject to the disability that, should the arm break away, it would signify the line was clear although the danger signal might actually be required.

In the same way, the green light might be entirely suppressed, but again a red or yellow light out would then give a " proceed " signal ; therefore a green light may be regarded more as a location light, the presence of which is a positive assurance to a driver that he may proceed unchecked.

It may therefore be assumed that a driver should look upon a green light, or a succession of such lights, as an assurance that the signalling system is functioning and that he should carry on at his scheduled speed, secure in the knowledge that should the need arise to check such speed a " cautionary " signal will be exhibited within braking distance of any " stop " signal.

The general interpretation of the indication given by a green light can therefore be summed up in the one word " proceed," no qualifying phrase being necessary.

The cautionary aspect indicated by a yellow light, meaning " caution—be prepared to stop at next signal " is a permissive aspect, *i.e.*, one that can be passed. At present, however, this is subject to it being displayed alone ; if surmounted by a red light, the combination forms a " stop " indication, which is wrong in principle, as should the red light go out, the signal forthwith becomes a permissive signal. The remedy for this will be dealt with later.

The yellow aspect can be accepted as a standard either alone or in combination, its separate indication always being " caution—prepare to stop at next signal."

The red " stop " aspect calls for little comment. When displayed singly or in combination with other red lights, it must always mean " stop " unless qualified by a less restrictive light properly displayed, as referred to later.

It is fortunate that the old anomaly of the distant signal carrying a " red " normal aspect is now disappearing, and this work should be hastened.

Recapitulating the above, the various signalling systems will have the three common basic light indications—

Red—Stop.

Yellow—Caution—prepare to stop at next signal.

Green—Proceed.

Before proceeding to the task of building up a series of aspects for general application, it must be pointed out that the economics of the subject must bulk largely in the decisions arrived at and that the ideal cannot always be achieved if this is taken into account, and to some extent compromises are necessary; therefore, in these proposals economics have been studied without undue sacrifice of clarity of aspect.

It is proposed first to set out the recommended indications for multiple-aspect signalling and then afterwards show how they can be adapted to manual block signalling.

Attached will be found a sheet of aspects giving the proposed standards forming appendix C, the various indications are numbered for reference.

Marker Light.

In view of the difference in the rules and regulations applicable to manual block and multiple-aspect signalling, it is highly desirable there should be some fundamental distinction between them whereby they can readily be recognised.

This can best be done by the adoption of the marker light, which is practically standard throughout the United States, where multiple aspect signalling is employed.

The Committee of the Institution of Railway Signal Engineers in their report, stated on page 11 :—

(6) "The use of marker lights is not recommended," leading to

(7) "Automatic signals which may be passed at danger, after a driver has waited at them for one minute should be distinguished by the letter 'A' which can be illuminated if required."

This proposal was subsequently embodied in the Ministry of Transport Requirements, 1928, see appendix D.

This recommendation of the Committee was undoubtedly due to lack of appreciation at that time of the rapid developments there would be in colour light signalling. It was felt that with the few isolated installations of multiple-aspect signalling where

it was anticipated that colour lights would be used, there would be no difficulties in recognition—a driver's local knowledge being regarded as quite sufficient. With the rapid extension of this type of signalling, and the more modern desire to apply colour light signals generally, the position is now entirely different.

The correctness of this contention in regard to the Committee's views is shown by their statement :—" It will also be necessary to see that the employment of two-aspect colour light signals shall cease, *unless such aspects agree with the recommended aspects.*"

As the portion in italics appears impossible of achievement, this paragraph ruled out the use of colour light signals in manual block territory, under the recommendations framed by the Committee. These may be regarded as the basis on which multiple-aspect colour light signals have been installed up to the present.

For clarity of aspect the marker light is now essential and forms the groundwork of these proposals.

Should the marker light be added to the manual block or to the multiple-aspect indications ?

As the use of colour light signals with manual block will for sometime to come be possible only by the use of low wattage signals in combination with approach lighting (making primary battery feed permissible), it is not desirable to load such installations (many single signals only) with additional lights. On the other hand, multiple-aspect installations will, as a general rule, necessitate a power supply, when the additional lights become a matter of little or no consequence.

For this reason the marker light should be added to multiple-aspect signalling, and be the distinguishing badge of the same, its application being defined as follows :—

> "Any signal which displays more than two aspects to a driver under normal working conditions, or any one or two aspect signal which forms part of a multiple-aspect sequence, shall carry a red marker light except where such signal leads to manual block territory."

What colour should the light be ? There is only one answer to this, and that is " red " ; for the reason that, in any combination, the failure of a lamp must not result in a less restrictive aspect being displayed, and a possible failure of the main lamp when the signal should be displaying the " stop " aspect must, therefore, be covered.

It has been said that a driver should not have to pass a red light, and in theory this is good if it was attainable in practice.

This statement was largely quoted at the time when the normal colour of the distant signal was changed from red to yellow, but in its general application the idea is a fallacy, as a driver has frequently to pass red lights, *e.g.*, directing signals on brackets and gantries, home signals provided with C.O. or other subsidiary signals, etc.

We are therefore forced to the logical conclusion that " a red light or lights must be regarded always as a ' stop ' indication unless used in combination with a less restrictive light."

As a cautionary signal, the red in combination with yellow is a more arresting aspect than the yellow used singly, and certainly far less likely to be mistaken for an extraneous light. In fact this possibility is thereby removed, but as a concession to the ideal the red need not be embodied in the " proceed " aspect, except at interlockings, where " directional " indications are given as described later under "Junctions."

What are the benefits to be derived from the use of a marker light ? These are that :—

(1) It forms a distinguishing badge as between manual block and multiple aspect signalling.

(2) Its position on the mast forms a ready means of distinguishing between interlocking and automatic signals, which now has to be denoted indifferently by the letter "A" in the case of automatic signals.

(3) It is a valuable asset in helping a driver to appraise correctly the yellow aspect. Owing to the proximity of red and yellow in the spectrum this is sometimes difficult and if a driver has once or twice, in hazy weather especially, mistaken a yellow for a red with consequent delay, he may possibly when, doubtful on another occasion, assume that a red is yellow, with serious results. With the two colours in combination this mistake is hardly likely to arise.

(4) It covers the failure of light due to a burnt out lamp bulb in the signal itself in automatic sections.

(5) It obviates light repeating circuits in interlocking territory.

(6) It can be used as a low speed signal.

Installation.

As regards installation, the following should be observed for the marker light :—

(a) The light should be of practically the same value in beam c.p. as the main light so that in the event of the latter failing during fog, a driver is still able to see the signal. In view of the practice to post no fogmen at colour light signals, this appears essential unless other means, as referred to later, are employed.

(b) The lamp should be fixed as far as possible at a standard height on the mast so as to be readily recognisable by its position. It should always be the lowest in any combination.

(c) For interlocking (stop and stay) signals the light should be vertically under the main light or lights.

(d) For automatic (stop and proceed) signals the light should be displaced horizontally about 10 inches to the left of a vertical line through the main light, so as to give a staggered effect.

(e) In the case of controlled signals capable of working automatically, both fixings (c) and (d) will be necessary, one or other of which will be switched in, according to the conditions operating.

(f) Where used solely as a "marker" light or as a subsidiary signal on plain road, to go out automatically when the signal is at "proceed," but to revert to R if the top G light fails.

Three-Aspect Signalling.

It has already been laid down what the aspects and indications are to be and these in combination with the marker light are shown on appendix C, Nos. 101, 106.

The application of such a system requires to be divided under two headings.

The Committee of the Institution of Railway Signal Engineers in their report state :—

> "With regard to electric passenger trains, in those cases in this country with which we are familiar, it will be found that the distances between signals are relatively great, taking into account the greatly superior accelerative and decelerative capabilities of electrically operated stock. The conditions may be regarded as analogous to signals spaced one mile or more apart on steam roads, with the obvious result that if of the three-aspect type, the cautionary aspect would be encountered

sooner than necessary, with consequent delay. The distances between signals on electric lines are based on the required headway, and are generally in excess of the distance required for braking and therefore, to avoid giving a caution signal until necessary, repeaters are provided. Therefore unless the service requires to be so intensive that the distance between "stop" signals is only equal to the braking distance, three-aspect signals would be a hindrance rather than an advantage to the operation of such a line.

It is therefore recommended that in such cases where colour light signals are employed, the signal immediately to the rear of a repeater be a two-aspect signal, showing red and green; repeater signals shall show yellow or green and other signals shall show the aspects given in the report."

The conditions visualised above are illustrated on the sketch, appendix E, diagram 2, where (a) represents a straight three-aspect installation where each individual signal can show either R or Y or G, and (b) represents an installation where the Y aspect is separated from the block signals, leaving R and G only, and is provided as a separate repeater fixed at actual braking distance from the respective stop-signals.

With this arrangement a train can run unchecked for an additional 1,000 yards, which is highly desirable in an intensive service.

It will be noticed that each repeater carries a red indication. This will not be encountered by a driver under normal running conditions and therefore needs no corresponding cautionary Y signal in the rear. Its function is to protect a train which may come to a stand between the repeater signal and the end of the overlap beyond the next stop signal ahead, against a following train which may pass the rear stop signal under the one-minute rule.

Although the "stop" signals in (b) show only two aspects, R and G, it will be appreciated that both (a) and (b) operate on three-aspect principles, the difference being that in (a) the aspects are combined in one signal, and in (b) they are separated.

As up to the present no attempt has been made to define these two methods, it is suggested that for the future they be referred to as

(a) Three-aspect signalling, type C,

(b) Three-aspect signalling, type S,

with the standard aspects and indications common to both types.

Four-Aspect Signalling.

The Committee of the Institution of Railway Signal Engineers in their report recommended that the indication to be given by the fourth aspect be "Attention—run at medium speed."

As the Y/Y aspect indicates that the next signal is "off," also that a reduction to a medium speed is necessary, an interpretation more definite from the multiple aspect standpoint is "Attention—pass next signal at restricted speed." The reason for the change will be appreciated better when junction working is considered further on in the paper.

The aspects involved in four-aspect signalling will be found in appendix C, numbers 107—114, and the application is shown by diagram 3, appendix E, from which it will be seen that an express train driver is advised two blocks in advance of any adverse signal; whereas a train running at medium speed or a train with superior decelerative powers, such as an electric train, can keep to schedule speed up to within one block of an adverse signal.

The arrangement is also applicable at complicated layouts where physical conditions dictate the position of the signals at less than high speed braking distance apart.

Five-Aspect Signalling.

Up to quite recently there has been no example of such signalling in this country although there is in America.

With the spread of electrification in suburban areas and consequent intensive operation at peak periods, where such lines are also used by high speed heavy express steam trains, it is almost certain that five-aspect automatic or semi-automatic signalling will be a necessity.

Although such signalling may not be the need of the moment, it should be borne in mind when a complete system of aspects is in preparation. Further, anyone who has closely studied the subject of the application of colour light signals to manual block territory will quickly see that if the fullest benefit is to be obtained, then in congested districts where at present boxes come closely together, a third cautionary indication—making a fifth aspect—will be required if the troubles experienced with present methods are entirely to be avoided.

To-day, with manual block signalling, short section working, rule 34 of the Block Telegraph Regulations applies.

With a properly designed system of multiple aspects, the necessity for this rule would disappear; where to-day it is almost impossible to get the distant signals off, due to the big margin required between trains, they would then be able to run unchecked. The value of this would be very great especially in foggy weather, and would be a definite aid to better time-keeping.

The choice of aspect is not wide, being limited to Y and G in combination, either as G/Y or Y/G.

It will at once be realised that the former, *viz.*, G/Y, is in constant use to-day, being the night aspect of a "distant" signal "on" under a "stop" signal "off"; it conveys to a driver the *most* restrictive cautionary indication, namely "caution —prepare to stop at next signal," whereas the problem is to find an aspect which will convey the *least* restrictive indication.

This is a very good example of the great need for care in selecting aspects. It is evident that G/Y must not be used in multiple-aspect signalling, as its indication requires to be totally different from the indication conveyed by this aspect when used in manual block signalling, where the signals may be equipped with powerful electric lamps making them the equal of colour light signals.

The alternative, Y/G, must therefore be envisaged and, by studying the sequence, it will be seen how suitable and logical this is; further, the aspect Y/G is one which does not exist to-day and, consequently, cannot lead to misunderstanding.

The sequence of aspects encountered by a driver between the "proceed" and "stop" aspects would be

G/O Y/G Y/Y Y/R R/R

cautionary.

It will be seen from this, by reference to the top lights, that there are three successive cautionary Y aspects which are graded by the lower light in a definite value of restrictiveness, whereby a driver is informed unmistakably that he has at least two signals ahead of him which are in the "off" position and that, emergency excepted, he will not have to stop until he reaches the third signal ahead.

The point may be raised that, in the event of the Y going out, a less restrictive aspect would be shown. It is essential to safeguard this, either by de-energising the control circuit of the lamp showing green, thereby causing it to revert to red, or preferably by changing the polarity, thereby giving yellow.

As the interpretation of the fourth aspect has reference to the signal ahead, *i.e.*, "Pass next signal at restricted speed," it appears desirable that the fifth aspect should convey a similar, though less restrictive, message, and it is therefore proposed that the interpretation of the fifth aspect be "Attention—pass second signal at restricted speed."

It cannot too strongly be emphasised that the necessity for sequences of two or three cautionary aspects is entirely dependent on the highest permissible speed and the consequent braking distance.

Only when the single Y/R does not allow sufficient braking distance is it necessary to introduce Y/Y, and again, Y/G is only necessary when Y/Y does not provide sufficient braking distance in the above circumstances.

The aspects involved in five-aspect signalling will be found in appendix C, numbers 115—124, and the application is shown by diagram 4, appendix E, from which it will be seen that an express train driver is warned three blocks in advance of any adverse signal, other considerations being as for four-aspect signalling.

Sequential Indications.

In laying out any multiple-aspect system, and also in applying colour light signals to manual block working, it is highly desirable that the unqualified cautionary aspect Y should always lead to R, especially in view of the fact that a driver may be able to see several successive signals ahead owing to their brilliance. If therefore he finds Y leading to another Y, or to a less restrictive aspect, his respect for this indication may be weakened.

This is already covered in manual block working by rule 42 which states:—"Whenever the distant signal is at danger (Y) the danger signal (R) must also be exhibited at the home signal, etc." On the other hand, the less restrictive aspect Y/Y need not necessarily lead up to Y, but can lead to a similar or less restrictive aspect than itself, such as G, as the indication conveyed by Y/Y, due, say, to a speed limit at the next signal ahead, does not necessarily apply beyond such a signal.

Overlaps.

The necessity or otherwise of providing overlaps in connection with colour light signalling is a subject calling for very careful consideration.

As is well known, the present standard overlap is a quarter of a mile. At one time the block regulations contained a qualifying clause that the preceding train must not only be ¼-mile clear, but also must be proceeding on its way, so preventing trains from closing up on one another—in other words, keeping them the length of a block section apart.

The elimination of this qualification altered the whole problem. High speed express trains are now accepted under full "line clear" up to an outer home signal, fixed ¼-mile from a junction fouling point.

Further, at the time of the alteration, no attempt was made to vary the overlap according to the requirements of maximum speed and gradient. Therefore the illogical position exists to-day that whether uphill or down, on fast or slow lines, the amount of clearance is the same.

What is the function of the overlap? It must be remembered that an overlap, as defined by track circuit, is an expensive item and therefore should not be indulged in unless its provision can be regarded as an essential, certainly not as a mere concession to tradition.

If it is to safeguard a driver who may have missed his distant signal and finds the home signal against him, then in many instances it is insufficient to enable him to pull up clear of an obstruction if he is running at speed. On the other hand, if its function is solely to safeguard a driver who may overshoot the "stop" signal, then with modern brakes and distant signals well sited at full braking distance from the "stop" signal, it is too much, and track capacity is thereby being sacrificed. It is beyond doubt that the ¼-mile overlap is of no value where a driver misses both "cautionary" and "stop" signals.

What, then, is the problem?

With systems of operation dependent on track circuits, one has to work to defined clearances, as there are no ready means of ascertaining that a train is continuing on its way, where personal vision is absent.

Two conditions have to be met:—

(a) Provision against end-on collisions.

(b) Provision against side collisions.

(a) May be further sub-divided into overtaking and head-on collisions, the latter applying mainly to single lines which require special treatment and need not enter into these considerations.

(a) *End-on collisions.* These involve trains following one another on the same line of rails. If one stops, then signal protection is necessary to prevent the train immediately following from running into the rear of the standing train. The amount of overlap decides how close a running train may approach to a standing train.

It is suggested that the use of colour light signals alters the problem materially; for a driver, as a result of momentary inattention or of temporary difficulties such as steam from another train, may miss seeing one colour light signal, but it is most improbable that he will miss two successive signals.

As any train is protected at least by a cautionary and a "stop" signal, braking distance apart, assuming that the cautionary (Y) signal is missed under normal conditions, a driver would see the "stop" (R) signal ahead, probably soon enough to enable him to stop at it. On straight track such signals can readily be seen for 1,000 yards in bright sunlight and considerably further at night; the correctness of this argument is borne out by the effective operation of a two-aspect automatic colour light system in clear weather.

On the other hand, should a driver see the cautionary (Y) signal and subsequently at reduced speed miss the "stop" (R) signal (which on straight track is most unlikely) no length of overlap, short of a "block" overlap, will safeguard him if he continues running, unless some form of A.T.C. giving a full brake application is provided at each "stop" signal.

It therefore appears that under *normal* conditions, providing that a signal is properly sited so that it can be seen by a driver at full braking distance away, based on the highest likely speed, then *no overlap* is necessary; but where such an extended view is impossible of attainment then an overlap *is* necessary, and must be of such a length that, added to the effective sighting distance, it provides full braking distance. Expressed as a formula, overlap = B − S, where B = full braking distance and S = sighting distance.

The overlap is rarely provided on straight track in America, but that country is comparatively free from fog; therefore the practice followed there will not necessarily suit British conditions, under which fog has frequently to be contended with during the winter months. This feature of operation will now be examined.

In manual block working, the difficulties inherent in foggy conditions are recognised and catered for in the relative rules and regulations by the introduction of fog block; rule 4, clause (e) states:—

> "Except where special instructions are issued to the contrary, during fog or falling snow, until the fog-signalmen arrive at their posts, and at signal-boxes where fog-signalmen are not employed, the 'is line clear' signal must not be acknowledged to the signal box in rear until the 'train out of section' signal or the 'obstruction removed' signal has been received from the signal box in advance and the block indicator worked from that signal box is in the normal position; nor must the 'blocking back' signal from the box in advance be acknowledged if permission has been given for a train to approach from the box in rear."

The recent report of the Automatic Train Control Committee (1927) also makes certain recommendations relative to working up to outer home signals at junctions differentiating between clear and foggy weather, which recommendations are generally in use.

A most important difference is therefore apparent between manual block and automatic working; namely, that the former is elastic and the latter is not. The subject of the overlap on straight track with automatic working must be looked at and decided in the light of the most onerous conditions which are likely to be encountered.

It is well known that in dense fog the oil-lighted semaphore signal often cannot be seen either by day or night, and a driver has to rely entirely on the fogmen.

On the other hand, experience has been sufficient to show that colour light signals can be seen in dense fog provided they are properly sited, and this excellent feature will become still more marked with the introduction of the additional marker light. They are, however, subject to the disability that under such conditions they cannot be seen at long range.

It may happen, therefore, that a driver misses the cautionary (Y) indication, and owing to the liability to loss of location in fog, is suddenly and unexpectedly faced with a "stop" (R) aspect whilst still running at speed; under such circumstances his only certain safeguard is an overlap which is not less than emergency braking distance.

Therefore if the high degree of safety of British railways is to be maintained unimpaired, their installations must be so arranged as to meet the worst conditions. Where manual control is absent, or only intermittently applied, as in semi-automatic signalling, then overlaps must be regarded as an essential part of the installation. They should always be equal to the emergency braking distance, whether more or less than $\frac{1}{4}$-mile, based on the highest likely speed and the ruling gradient. Suitable formulae are available for readily ascertaining this.

Where a close headway is required on an automatic three-aspect installation, the overlap may equal a block section, generally referred to as a full block overlap system. Each train is then protected by two signals at "stop" (R). (See diagram 5, appendix E).

Where mixed traffics are dealt with it will be appreciated that it is out of the question to decide the overlap length on the basis of unbraked stock. Drivers of such trains must run at such a speed as to have their trains under full control, having regard to the local circumstances and the conditions appertaining thereto.

In the case of multiple-aspect installations catering for electric and steam trains and necessitating four or five aspect signalling, the overlap would be based on the emergency braking distance required by an electric train tripped at an adverse signal. This is invariably less than that required by the steam train, but the latter is helped by the fact that the driver receives additional advance information of a "stop" signal ahead given by the Y/Y and/or Y/G aspects, and therefore the need for the full overlap for steam operation is materially reduced.

It may therefore be said that the necessary length of the overlap is in inverse ratio to the number of aspects.

It is perhaps desirable to point out that the overlap already referred to must, in any automatic section having the one-minute rule in force, be a true overlap, *i.e.*, a separate section of track circuit as distinct from an overrun, which consists of continuing the approach track circuit for a given distance beyond the signal. The reason for this is that the overlapping portion must hold the signal immediately in the rear at "danger"; otherwise, when a train has broken down in such overlap, a following train passing the rear signal at "danger" next encounters a signal giving

possibly a full " proceed " aspect with an obstruction immediately ahead. (See diagram 6, appendix E.).

(b) *Side Collisions.* This involves the protection of trains which may be passing from one line to another, as at junctions, or into or out of adjacent sidings, against other trains which may be approaching on the straight line which eventually fouls their pathway.

It may be said that all such connections must be manually operated either from signal cabins or from ground frames by power or by mechanical means.

It has already been seen that manual block operation is elastic, as the working and acceptance of trains can be varied to suit prevailing conditions ; therefore where manual control is in operation it is found that circumstances vary according to the operation of traffic between any given points by (a) telegraphic block or (b) track block.

In the former case, in the event of fog arising, a signalman is at once able to introduce fog block working and thereby provide adequate clearances between conflicting movements ; but here again track capacity must be taken into account. In the latter case he has no power to " refuse " trains which arrive at his " interlocking " in accordance with the clearances as defined by track circuiting.

In considering this application it must be borne in mind that, irrespective of atmospheric conditions, the relative positions of any connection and its protective signal(s) are constant ; therefore additional clearance can only be provided by holding an oncoming train at the cabin in the rear in the case of telegraphic block, or at the next signal in the rear in the case of track block.

It has been shown that in laying out overlaps against rear-end collision in automatic sections, limited overlaps only, appear necessary in clear weather, but that the actual installation has to be determined by the needs of foggy weather, which calls for an overlap equal to full braking distance. The same requirement appears to be fundamental at interlockings where facilities are required for full " line clear " acceptance at any time, *i.e.*, the outer home of to-day, but at other interlockings the limited overlap B—S already referred to will meet the case.

There is no doubt that by judicious placing of signals, many of the restrictive effects of the present regulations could be overcome. The introduction of colour light signals, providing that the

possibilities are realised, should result in increased track capacity and freedom of operation without in any degree lowering the standard of safety.

An anachronism of modern signalling, *viz* rule 5 of the Block Telegraph Regulations, should gradually disappear, as with the present high degree of development in signalling, the provisions of this rule are becoming unnecessary. The substance of the rule is either a tacit admission that a driver cannot be expected to stop at a given point by signal indication alone, or else, what is more probable, it is a survival from the days when at junctions the "stop" signals did not protect the fouling points.

It is therefore suggested that protective controlled colour light signals be arranged as follows :—

(A). For general working, the position of the home signal shall be such as to provide an overlap (see below)* in accordance with the formula already quoted, *viz.*, B—S, subject to the provision of a minimum clearance between signal and fouling point of 200 yards, (see diagram 7, appendix E.).

Provided that the cautionary signal in the rear is fixed at full braking distance and carries a marker light, or alternatively is fitted with an automatic detonator placer operative in case of light failure, then the following regulations will apply :—

Clear Weather. All trains to be accepted up to the home signal at danger when the junction is occupied.

Foggy Weather. All trains to be kept back at the cabin in rear (*i.e.*, refused) in the same way as is done to-day, *even in clear weather.*

Notes :—

(i) The definition of foggy weather would have to be tightened. Weather should be regarded as "foggy" when visibility is less than half-mile.

*(ii) Where the next stop signal in the rear is a controlled signal as distinct from an automatic signal, when track circuit is provided the overlap can be an extension of the 200 yards circuit usually provided approaching the home signal. (See diagram 7b).

It will be appreciated that with the above arrangements, the operation of a railway will be greatly facilitated during the major portion of the year, especially in the summer, at periods of maximum traffic.

(iii) Where the distance to the rear cabin does not permit of the home signal being kept back by 200 yards, the present day block regulations to apply, *i.e.*, trains to be refused when the junction is occupied.

(B). At certain junctions where the exigencies of traffic call for " free " acceptance at all times, in order to meet foggy conditions, a somewhat different arrangement will be necessary.

As overlaps equal to the full braking distance are necessary on straight track with automatic signalling to meet the onerous conditions arising during fog, so at a junction, provided that free acceptance is required at all times, there must be full braking distance between the protective signal and the junction fouling point. This is shown as signal 2 on diagram 8, appendix **E**.

It is also desirable that there should be an inner home signal No. 3 at the junction fouling point and a cautionary signal at full braking distance from No. 2.

The working would be as follows :—

Clear Weather. When the junction is being occupied by a conflicting movement, an approaching train will find No. 1 at Y and Nos. 2 and 3 at R until the train reaches point b, 100 yards from No. 2, when the latter will change from R to Y. The train is thus allowed to draw down to No. 3 at R at reduced speed, and for this reason no overrun is provided.

Foggy Weather. Under similar circumstances, No. 1 will be at Y and Nos. 2 and 3 at R until the junction is cleared, so allowing No. 2 to be taken off.

On examining diagrams 7 and 8, it will be appreciated that, in the case of 7B, the varied acceptance in foggy weather is a matter of rules and regulations only, as to-day ; but for 7A, means have to be provided to convert the rear automatic A into a controlled signal so that trains can be held at it and, in the case of diagram 8, to vary the working of the outer home No. 2. The controls otherwise are the same, irrespective of the type of signal in the rear.

It is proposed to do this by means of a " fog switch " fixed on the instrument shelf which when operated would bring into force the restricted controls as indicated, such switch to be fitted with a Veeder counter to register each actuation. It would be the responsibility of the signalman to record each movement in the train register book, together with the relative time of each operation.

Approach Lighting.

In America, with a comparatively sparse traffic, approach lighting is in almost universal use in automatic territory, as it

provides a very real economy even in those cases where the signals are lighted from a power line.

In this country little has been done, solitary examples being at Nottingham, Carrington (1927), and at Eryholme, on the London and North Eastern Railway (1928).

It will be many years yet before power supplies are universally available in this country, and therefore for isolated cases recourse must be had to approach lighting if primary battery operation is to be economically possible.

When laying out the circuits, the time of illumination should be kept to a minimum, and only be operative whilst a train is on the approach track, which, generally speaking, would extend to the next signal in the rear except where such distance is in excess of the sighting distance.

It will probably be said " supposing the signal does not light up " ? It must be borne in mind that this is to a large extent the antithesis of a light going out and does not really introduce any extra risk. The situation can be met satisfactorily by the provision of marker lights in multiple-aspect signalling or by detonators automatically placed should a light fail. A further safeguard is to restrict to Y any signal preceding that at which the light has failed.

Where approach lighting is employed on parallel tracks signalled in the same direction, *e.g.*, " up fast " and " up slow," a train approaching on either line must light up the signals applicable to both roads, otherwise a driver may be seriously mislead. Approach lighting is a method of operation deserving every consideration, as only by its aid can colour light signalling be made immediately applicable to general conditions.

Replacement.

Closely allied to the subject of approach lighting is that of the replacement of the light to red on a signal being passed by a train.

Owing to the long distance at which colour light signals are visible, especially at night, overlapping is possible. For this reason it is generally desirable they should be replaced by track control unless they are a considerable distance apart and half rotation locking is in force.

Shunting Signals.

The Committee set up by the Institution of Railway Signal Engineers in their report suggested that elevated shunt signals should show R and Y and that ground shunt signals should show W or R and G.

In view of the subsequent clear definitions laid down in the Ministry of Transport Requirements, 1928, it does not appear necessary or desirable to depart from them. Therefore for shunt signals, whether of the semaphore or colour light type, the present indications should remain, *i.e.*,

On—Red or yellow.

Off—Green.

The Committee further stated :—" It is however recommended as better practice to dispense with colour lights in the case of ground shunt signals utilising illuminated " position signals in lieu of the same."

This recommendation is a sound one. A suitable type of signal to employ is the internally illuminated banner signal, whereby a position signal is available both by day and night, the arm being coloured red or yellow as required.

Subsidiary Signals.

Call-on signals. In June, 1929, a Railway Clearing House Committee tabled a recommendation that :—" It was considered desirable not to use colour aspects for ' calling-on,' ' warning ' and ' shunt ahead ' signals in colour light installations, but to adopt an optical projector type or banner type of signal in such areas."

This recommendation may be regarded as present British practice, but it was certainly a compromise and a concession to tradition. The decision apparently arose out of a difficulty experienced by the London Midland and Scottish Railway in their recently opened colour light installation at Manchester, where following semaphore practice, they had used white as the normal light and green to authorise the calling-on movement. They quite naturally found that the drivers mistook the so-called white light for yellow and passed the signal at " danger."

In view of the fundamental differences between multiple-aspect colour light signalling and ordinary semaphore signalling with consequent night aspects, it appears to be a misconception to attempt to superimpose the latter on the former, as they are

totally distinct. This is where the Americans have been fortunate, as they are not hampered by tradition nor have they the conservatism of the British ; in developing a new system they were in no way influenced by considerations applicable to older systems.

It having been laid down that multiple-aspect signals shall be equipped with marker lights, it is a natural step to use such an indication as a low or shunting speed signal as required. The Americans do this, exhibiting a yellow light, which is then known as a " know nothing " signal ; in other words, it merely authorises a driver to pass the signal prepared for any eventuality. (See figure 13, appendix A.). We cannot do better than follow their example, using a small yellow light as the " off " indication of a call-on signal, which should bear the same interpretation as that laid down in the rule book relative to semaphore call-on signals.

Installation details will be as follows :—

Normal aspect—R/R as for marker light.

Proceed aspect—R/(y).

Circuits so to be arranged that R/(y) is not exhibited until the train has been brought to a stand. In view of the extreme importance of a proper interpretation of this aspect, arrangements to be made as subsequently shown so that this aspect may not be exhibited under any other circumstances.

Permissive marker light signals. Reference has already been made to the use of the one-minute rule in automatic territory. Such a rule is necessary to avoid trains being unduly delayed in the event of failure of the track circuiting or other parts of the apparatus, resulting in a permanent danger signal being exhibited until the fault is removed.

Where train-stops are provided, a double stop is involved as, after waiting at the signal and then proceeding, the train is immediately and forcibly pulled up by the application of the train-stop, which is somewhat annoying and disturbing to passengers who are not aware of the circumstances.

With the adoption of the R/(y) call-on aspect this difficulty can be overcome by making each marker an automatic call-on signal controlled by a time element relay so arranged that, on the approach track being occupied with the signal at " danger," the marker will change from R to (y) after the expiry of one minute or longer, plus an allowance to cover the time required

between the train entering the approach track and coming to a stand. The circuit which changes the marker from R to (y) will also operate the train stop, so obviating the needless second stop.

With the adoption of this arrangement, the marker position would be vertical, *i.e.*, each signal would be a "stop" signal, but in order to meet the improbable contingency of a failure of a marker light to change to (y) it would still be necessary to introduce a rule to cover the passing of such signals at danger. It is proposed that such signals should still carry an identification letter A, which need not be illuminated, authorising passing after a wait of three minutes.

In view of the expense involved, such permissive marker signals are not proposed for general use, but only on roads which have an intensive service and are equipped with train-stops. In such cases their adoption would undoubtedly be beneficial both from the working and psychological standpoints, as the arrangement would practically eliminate the passing of danger signals.

Grade or tonnage signals. In America certain automatic signals carry the letter G or T on a plate, projecting from the side of the signal. This indicates that, due to a heavy rising gradient, such signals can be passed at "danger" by heavy freight trains, without first stopping to give effect to the one-minute rule. There is no similar relaxation in the case of passenger trains.

This arrangement might very well be adopted in similar circumstances in this country on rising gradients exceeding 1 in 100, but it would be necessary to illuminate the sign for night working.

Warning Signal. In semaphore practice this is denoted by a miniature arm of the call-on type exhibiting the letter W. There is no need to attempt to provide a special aspect for this in multiple-aspect signalling, as it is already given in the clearest possible manner by the Y aspect: "Caution—prepare to stop at next signal."

All that is necessary is to ensure a reduction in speed. This can be done in a most flexible manner by providing a short approach track to the second signal and arranging, when the conditions ahead call for it, that the rear signal does not change from R to Y until the train reaches the approach track. The length of the approach track will determine the desired degree of speed reduction.

It will be appreciated that the obstruction will be primarily protected by two signals at R and one at Y, as laid down for junction working with free acceptance, see diagram 8, appendix E.

Shunt or draw-ahead signal. In semaphore practice this is denoted by a miniature arm of the call-on type exhibiting the letter S. It is not anticipated that the call for such a signal is likely to arise in multiple-aspect territory, but should it be found necessary it should conform to the aspect of a shunting signal as referred to later under the heading of " Speed signalling."

Fog repeaters. With the elimination from surface lines of the two-aspect system of automatic signalling (see left-hand column, appendix C) there appears to be little need of repeaters provided specially for foggy weather. It is rather a case of using them constantly as in three-aspect signalling (type S, diagram 2, appendix E) to get the last ounce out of an installation and also, in other instances, to give advance indication of the aspect of a signal where, due to local circumstances, sighting distance is poor. As regards the latter, it appears desirable that in multiple-aspect signalling the repeater shall " repeat " the aspect of the signal in rear rather than the signal in advance as recommended by the Committee of the Institution of Railway Signal Engineers so obviating the necessity of the white light with the word " fog " superimposed.

Where the repeater is full braking distance from the relative " stop " signal, it shall carry a staggered marker light, but where fixed at less than the full braking distance and Y is separately shown, then it shall be identified by the letter R, which need not be illuminated.

Junctions.

In the U.S.A. and, to a limited extent, in this country, one hears reference made to " speed " signalling. Its protagonists have been as " voices crying in the wilderness," as little impression has yet been made on the prejudices engendered by many years experience of " route " signalling. The antagonists have had matters all their own way by airily referring to 27 different aspects which are supposed to build up " speed " signalling; having quoted this often without any attempt at comparison, they regard the matter as disposed of until someone else is foolish enough to raise it again.

It is high time this subject was carefully considered as it is a concomitant of colour light signalling and cannot logically be divorced from it.

What is speed signalling, and is it applicable to this country?

There are certain fundamental differences in the conditions obtaining in the two countries which make the problem different, and with the much greater density of traffic and the frequency and variety of junctions to be found in Great Britain, the policy to follow is to select only those features which offer undoubted advantages.

It must be appreciated that speed *per se* is entirely relative to any given local circumstances. It is out of the question to attempt to tell a driver at what speed he should run his train; in fact, to try and do so within narrow limits would be wasteful and futile, seeing that locomotives in this country are not equipped with speedometers.

On the other hand, if "speed" can be divided into, say, three parts, considerable benefit may accrue.

A limited attempt at "speed" signalling has always been accepted practice in this country. The importance of diverging lines and their limiting speeds in the case of crossovers is always indicated in semaphore signalling by the relative height of dolls, which are stepped usually in heights varying by about 2-ft. 6-ins., the main route being always the highest doll.

This principle would still apply, but instead of carrying the signals on separate dolls, there appears to be no reason why, generally speaking, they should not be grouped on the one mast, the "speed" indication being divided into three parts, so that the top light would indicate high speed, the centre light medium speed and the bottom light low speed. Nothing could be simpler to remember; the arrangement is its own explanation.

As already stated, "speed" is always relative; what may be high speed at one point may be the medium speed at another and *vice versa*, but the third or lower speed is a non-variable, and would refer to a low or shunting speed of not more than 10 m.p.h. according to the aspect displayed.

Medium speed cannot be regarded as the average speed, as obviously it would be unsafe for a train which had been running at 80 m.p.h. to be diverted from a fast to a slow line at 45 m.p.h. It must be relative to the route to be taken, hence the necessity for local knowledge on the part of a driver.

Definitions of the terms high, medium, and low speed should, therefore, be :—

High speed, the highest permissible speed at any given location.

Medium speed, a restricted speed suitable to the diverging route (*i.e.*, the speed limit) generally not exceeding 30 m.p.h.

Low speed, shunting speed.

All the above are further subject to the aspect displayed, see appendix C.

Junctions come under two categories, (1) those between running lines both continuing in the same direction, and (2) geographical junctions where a line diverges in two or more directions.

It is proposed that, in the case of (1), the signal reading over the junction facing points shall always be as Nos. 134, 144, 155, appendix C ; similarly in the case of (2) this arrangement shall apply where, over an ordinary double junction, there is no restriction on one route but a considerable reduction of speed is required on the other, varying by not less than 20 m.p.h. This arrangement would be very advantageous in the case of parallel lines where, as a rule, there is little more than a 10 foot space between lines in which to fix the signals.

This means that a bracket signal has to clear the loading gauge, resulting in considerable elevation, and as height is very detrimental to colour light signal efficiency in foggy weather, this factor alone makes it desirable to adopt any means which will permit the signals being kept at a low elevation.

With the introduction of the arrangement described above, the present rule that the top arm (light) always applies to the line on the left, the second signal to the line next in order from the left and so on, will have to be modified.

Where there are more than two routes which cannot respectively be graded under high, medium or low, also in the case of two-way junctions where both routes are restricted or else are unrestricted and vary by less than 20 m.p.h., then the junction signals shall embody such horizontal displacement as may be necessary clearly to define the routes to be followed.

Before passing on to the consideration of " distant " signal aspects, reference will be made to the bottom or low speed signal. This occupies the position of the marker light but is capable of displaying other aspects than red.

It has already been seen that when turned to (y), it gives

the call-on aspect R/(y). This is in no way affected by the additional R of a junction signal, giving R/R(y); the interpretation remains the same, but direction is absent and generally appears unnecessary.

There is, however, a fundamental difference between the bottom light and the two above it.

Both the high and medium speed indications are multiple-aspect signals, *i.e.*, they give advance information of the aspect of the next signal ahead; but the low speed indication, being a "shunt" signal, does not do this but follows the general principle laid down under the heading of "shunting signals."

The "off" indication is therefore green, meaning "proceed at low speed." The green has no reference to the aspect of the next signal ahead, but merely indicates a clear path to be traversed at low speed. The green light, as for yellow, should be a small one.

It is regarded as essential that advance warning of incorrect routing should be given to a driver in sufficient time to prevent him from passing on to the incorrect route at speed and suffering the delay consequent on the provision of wrong line orders. Under the heading of distant signals it will be shown how it is proposed to meet this problem.

The Ministry of Transport Requirements, 1928, page 6, line 41, states:—

> "At diverging junctions, one distant signal only should be provided, worked for the junction line over which the highest speed is permissible, unless in exceptional circumstances more are essential.
>
> Where special circumstances, *e.g.* permanent speed restriction, justify the adoption of an unworked signal, it should be secured in the warning position and not coupled up or duplicated for directing purposes."

The above regulation has given rise to a great deal of controversy, as traffic officers rightly point out that in time of fog it has a seriously restrictive effect just when they need every possible help; for on the diverging route drivers have to feel their way from signal to signal, which is very onerous in the case of heavy mineral and freight trains.

In such a case colour light signalling can provide a very effective remedy, as the requirements of both parties are met.

Assume that the junction is protected by the three vertical lights as already explained. Then the signal in rear will display

Y/R	leading up to	R/R/R/
G/O	,, ,,	G/R/R/
	,, ,,	Y/R/R/
Y/Y/R	,, ,,	R/G/R
	,, ,,	R/Y/R

The Y/Y conveys the two definite messages (a) that the signal ahead is "off," (b) that the signal ahead may only be passed at restricted speed.

It is a matter for careful consideration whether it would not be an excellent arrangement to provide a speed lamp either at the rear or "distant" signal or at a midway point where brake application is first necessary, capable of being illuminated with the actual speed limit figures of the junction ahead, such to be visible only when the Y/Y is exhibited. (See appendices F and G).

In order satisfactorily to give the "distant" indication when the junction indication calls for Y/Y and/or G at the rear signal, applicable to alternative geographical routes, the following arrangement is proposed. The rear signal to carry two separate yellow side lamps which are fixed right and left of the green lens; these to be normally out, lighting up only when the G or Y/Y aspect is energised, the right hand lamp lighting for the left hand route and *vice versa*. A driver would thus be provided with the same aspect as he obtains to-day with semaphore signalling.

Diagram No. 1 to 4, appendix F, show the application of the principles enunciated in regard to junctions.

Terminal working. In dealing with junction aspects the special requirements of terminal stations must be considered.

At many terminal and also some through stations there are two train berths at a platform and the problem is how to advise an approaching driver that he has a clear platform or that the leading berth is already occupied.

Certain instances have been dealt with in this country as follows, the aspect being that given by the last entering signal.

G—clear to buffer stops.

Y—one train in, second berth clear.

CO—both berths occupied.

Theorists point out that it is wrong to give G leading to R,

the light on the buffer stops, although it is admitted that a driver can hardly fail to know that he is entering a terminus. In view of this and of the desirability of having G available for its correct function at large through stations where these conditions are in force, it is recommended that the three vertical light "speed" signal be used with the following applications :—

Y/R/R—Line clear to buffer stops (terminal). Line clear to next signal (through station).

G/R/R—Line clear to next signal (through station) and next signal at Y or G.

R/Y/R—One train in, second berth clear, or line clear to buffer stops of bay line.

R/R/(y)—Call on—*e.g.*, engine backing on to train.

R/R/(g)—Draw past for shunting purposes and entry to spur roads, carriage landing, etc.

The above can only be regarded as a general principle owing to the variety of layouts, many of which need special treatment. An effort should be made to grade routes into approximately equal lengths for given aspects, and if local circumstances dictate the desirability of more detailed direction, route indications can be used.

Both at terminals and at running junctions, where the medium and/or low speed signal applies to more than one route, separate levers working such signal(s) should be provided for each such route, as a help to the signalman in correctly setting up the route for which a given movement is intended.

At terminals and other large stations it is often necessary to signal trains on to the facing road for shunting purposes and whilst the Ministry of Transport Requirements, 1928, state that "a special type of shunting signal for wrong line movement is not considered necessary," local circumstances often make it very desirable. To meet such cases in colour light signalling territory where it is desired to avoid the use of a route indicator, a suitable "off" indication can be given by a lunar white light with a black cross painted diagonally across the lens.

In appendix G will be found the various aspects likely to be met with in a complete system of multiple-aspect colour signalling as set out in this paper.

Standard Heights and Clearances.

As an explanation of the various diagrams which are drawn on the assumption that the S.A. type of signal is used, two

dimensional sketches are attached (appendix H) showing typical fixings.

No. 1 shows a speed junction signal fixed in the space between two lines of way, the low speed or marker light being at a standard distance of 4 feet below the medium speed lamp, which should generally be 12 feet above rail level. The high speed signal is also 4 feet higher than the medium speed signal, which allows of an intermediate Y or G light to be added for four or five aspect signalling midway between the high and medium speed lamps where it is common to both.

No. 2 shows an automatic signal with staggered marker light, the main lamp being at 12 feet above rail level and the marker light 4 feet below it as in sketch No. 1.

Where a fourth and/or fifth aspect is required the additional lamp is fixed 2 feet above the main lamp as shown by dotted lines.

In all cases every effort should be made not greatly to exceed these heights and always to fix the signal to the left of the line to which it applies. The centres between lamps should not be varied.

Application of Colour Light Signals to Manual Block Signals.

The recent Report of the Automatic Train Control Committee (1927) laid great stress on the benefits to be obtained by the introduction of colour light signals.

Clause VI (3), page 8, reads :—"With regard to ordinary distant signal posts, we have been impressed, having regard to the more intensive service of high speed traffic during recent years, with the desirability for providing better lighting. Little alteration has been made for a long period in the actual methods of lighting these signals, which dominate the conduct of high speed traffic. Lighting, more brilliant and penetrating in character, would be a strong factor in determining the acceptability of an economical form of protection to prevent accidents arising, in poor atmospheric conditions, from failure of enginemen to observe distant signals. The importance of better location and correct elevation of signal arms and lights from the point of view of improving visibility in similar difficult conditions (to which attention has often been drawn in accident reports) has also been noted."

Clause XI (1), page 18, reads :—"*Indirect methods of increasing security*. (b) To increase the illuminative and penetrative power of signal lights themselves."

"With regard to (b), electric beam light signals with high illuminative power and correct focussing have, wherever they have been adopted, met with general approval. They have during the past three winters never failed to be visible at an adequate range even in bad conditions of fog. So much reliance is nowadays placed on them that fogging services are not called for at signals of this type."

One very important point which the Committee apparently failed to appreciate when making the above recommendation was that the installation of better lighting introduced a further risk which increased in magnitude in direct ratio to the intensity of the illumination ; that is the risk due to the failure of the light.

With the present type of oil lamp, it needs a very real effort on the part of a driver to find a signal in bad weather and he takes every possible care to ensure that he does so ; but with colour light signals, their intrinsic brilliance may become a source of weakness, as the better it is, both from the point of view of brilliance as well as of reliability, the more likely will a driver be to rely on its efficiency to draw his attention to his location and warn him in adequate time, in the case of a distant signal, of the state of affairs ahead.

Should the signal fail during a train's passage through a section, a driver may very seriously be misled by the absence of such a signal, which on a dark wet night may not be realised, and thereby he may approach a stopping point at too high a rate of speed.

It has already been seen that the marker light in multiple-aspect signalling is one solution of the difficulty, but as it is not proposed to embody this in manual block territory, something else is necessary.

It is therefore proposed that all isolated distant signals of the colour light type be equipped with an automatically operated detonator placer so arranged that it is normally off the rail. It can be held in that position against gravity or a spring through the medium of an electric clutch, the coils of which are in series with the signal lamp bulb.

Any failure of light will thereby be brought to a driver's attention and adequate warning given.

The application to this form of signalling of daylight colour light aspects can be effected in two different ways :—

(1) By substituting electric lamps of the Corning-Lebby type, having a high c.p. in place of the ordinary oil or gas lamp, or (2) by replacing individual semaphore signals by complete signals of the colour light type.

The following notes show what precautions must be taken in carrying out either of the above conversions in order to avoid giving aspects contrary to those already laid down for multiple-aspect signalling and set out in detail in appendix C.

(1) *The use of electric lamps in place of oil or gas.*

As the beam c.p. of such lamps can be equal to the ordinary colour light signal, no distinction between the two types can be looked for in inferiority of light. In the case of " stop " and cautionary signals (R and Y) the absence of the marker light serves to distinguish them from multiple-aspect signals ; but even this does not hold good with the " proceed " (G) aspect, and in view of the varied interpretations to be placed on G in manual block territory it is essential that this type of signal should be clearly defined.

The problem is a difficult one to meet both economically and clearly by lighting alone, and it is therefore proposed that the best solution is to retain the arms.

This proposal has the following advantages :—

(a) No interference with the normal balance of the signal.

(b) Obviates having to provide indicators for those signals a rear view of which is obtainable from the cabin.

(c) Is a clear indication by day that manual block working and the consequent rules and regulations are in force.

(d) Costs nothing for additional equipment.

The disadvantage is that, generally speaking, the arm is not available as a night indication. This, however, need not be regarded as serious, since experience in other and similar directions has shown that a driver learns his road and signals by day and remembers the conditions at night, *e.g.*, diamond and D signs, unlighted notices, and particularly the red light at one time used for the " on " indication of a distant signal.

The next point to be observed is that in order to avoid the misleading sequence of aspects shown by diagram 1, appendix

E, the operation of rule 40 (a) should be electrically enforced by the provision of a short track circuit or check contact outside the home signal. It does not appear necessary to extend this control to intermediate signals where they occur between the home and starting signals.

Referring to appendix C, in the right hand column will be found the manual block equivalents of the various aspects of multiple-aspect signalling and the following examples call for comment.

No. 11. Where co-acting arms are provided, it will generally be unnecessary to provide an electric lamp in the top arm.

No. 12. Is an aspect which is disappearing as the "on" colour of distant lights is changed.

No. 13. This is in direct conflict with the call-on aspect of multiple-aspect signalling (see Nos. 125, 126 and 127), and should not therefore be perpetuated. Fortunately an easy solution is available, and that is to switch out the light in the distant signal when the top light is red, as when this is displayed it is immaterial to a driver what the aspect of signals ahead may be. Immediately the top arm is lowered and changes to green, Y or G should come up below.

Note :—Consideration should also be given to the adoption of this principle in connection with ordinary oil-lighted lamps.

At the present time the change to the yellow light has introduced a very real difficulty by reason of the much higher transmission value of the yellow glass. The comparative brilliance of the latter tends to obscure the red light above and, as this introduces a risk that drivers may pass a danger signal, complaints have been received. An attempt has been made temporarily to meet the difficulty by reducing considerably the size of the yellow spectacle glass.

It appears that a better solution following on the lines advocated above would be to provide a shield or blinder which would obscure the yellow light when the top arm is at danger, *i.e.*, red.

No. 14. The suggestions relative to Nos. 11 and 13 both apply in this case.

No. 20. To be provided with automatic detonator placer, arranged to put a detonator on the rail in the event of light failure.

No. 21. Double yellow in its application to co-acting arms should not be permitted.

As a general rule the remarks relative to No. 11 would apply.

No. 22. This aspect is frequently met with and does not conflict with any proposed aspect.

No. 23. As No. 12.

No. 24. Must never be perpetuated where electric lamps are provided, the spectacle being reglazed yellow as in No. 20.

No. 25. As No. 11.

Nos. 30/34. Serve to illustrate the varying values of green in manual block; whilst all mean "proceed," the length of territory to which this permission applies is quite indefinite.

Nos. 40/41. With the introduction of R/(y) as the standard call-on aspect in multiple-aspect signalling, it appears highly desirable to conform to this for manual block operation, in which case, the "C" on the illuminated screen would no longer be necessary.

Nos. 42/43, 44/45. To remain as at present, with relative letter on illuminated screen.

Nos. 40/42/44. It is proposed that no normal light be shown in the subsidiary arms, mainly owing to the difficulty in finding a suitable colour.

If white were used there would no doubt be a repetition of the experience of the London Midland and Scottish Railway at Manchester, where it was interpreted as yellow or green. If red were used, it would appear to be a marker light leading a driver to mistake the signal for a multiple-aspect signal and thereby interpret incorrectly the green aspect of the top arm.

Briefly summarised, the following requirements are desirable in applying electric lamps of high beam candle power to manual block signalling.

(a) Signal arms to be retained.

(b) Compulsory rule 40 at home signals.

(c) Lamp in top arm(s), generally unnecessary with co-acting arms.

(d) Distant "on" to be yellow.

(e) Where a "distant" signal is fixed below a "stop" signal, the light in the former to be switched out when the "stop" signal is "on."

(f) Automatic detonator placers to be provided at isolated distant signals.

(g) Call-on aspect to be R/(y) with approach control and no normal light.

(h) Normal light to be dispensed with in subsidiary signals W and S.

Note:—The application of (e) and (g) to ordinary semaphore signalling is deserving of consideration.

(2) *Replacing individual semaphore signals by complete signals of the colour light type.*

It will at once be appreciated that, contrary to No. (1), there is no difference in construction whereby such signals may be distinguished from colour light signals used as multiple-aspect signals. This is where great care is essential to ensure that conflicting aspects are not given.

It has already been laid down that multiple-aspect signals will carry marker lights in contradistinction to manual block signals. This, however, does not apply to the "proceed" aspect.

It is therefore proposed to deal first with the three main signals in manual block operation, *viz.*:—distant, home, and starting signals, and then by means of diagrams to show the method of application.

Distant signal. The standard colours for this signal are:—yellow—caution, and green—proceed; these agree with the aspects shown in appendix C, Nos. 20/32.

The distinction from multiple-aspect signalling is given when

On—by the absence of the marker light.

Off—no distinction is considered necessary. See remarks under "proceed" indication.

The automatic detonator placer will be necessary for reasons already quoted.

A very valuable addition which can be made is a third-aspect R, used only when a train is between the distant and home signal, and serving to protect that train against a following one which may improperly enter the section.

Home signal. The standard colours for this signal are red—stop, and green—proceed, the latter being given even though the starting signal (where such exists) is at "danger."

Here the comparison between the two systems of signalling utterly breaks down.

It would equally be wrong to adopt yellow as the "off" indication of the home signal, as with all signals "off" and the "distant" showing clear, a driver would unnecessarily be checked at the home signal; the conclusion, therefore, must be that whenever a home signal is converted to the colour light type it should be capable of showing *at least three aspects, viz.*, R or Y or G, the additional expense of which would amply be repaid by the additional facilities thereby given.

This decision would result in the addition of the marker light, making the aspects R/R, Y/R, G, and possibly R/(y) if a call-on signal is required.

Starting signal. The present standard colours for this signal, *i.e.*, R and G, are as for the home signal and, assuming that no advance starter is ahead or distant for the next cabin below it, these colours can be repeated as a colour light signal without fear of any misinterpretation.

Application to actual examples. On appendix J will be found a series of diagrams illustrating the application of colour light signals to a number of typical examples.

Fig. 1. Provide C/L distant signal.

Requirements :—

Yellow—Normal aspect.

Red—When train between signals Nos. 1 and 2.

Green—When signals 2 and 3 both "off."

Diagram 2. Where due to bad sight, such as an overbridge, it is desired to convert the home signal No. 2 to colour light type, this would usually be done by method No. (1), *i.e.*, by adding electric lamp(s), modifying the signal construction to suit and observing any of the relative requirements (a) to (h) on previous pages.

Diagram 3. Where it is decided to convert all signals to colour light type, every effort should be made to provide braking distance between successive signals.

No. 2 becomes a three-aspect signal with marker light; the latter is also added to No. 1 (staggered).

Where braking distance is insufficient between Nos. 2 *and* 3 the sequence of aspects will be :—

No. 3 at R.

No. 2 at R until check contact reached 200 yards from signal when Y is given.

No. 1 at Y.

Where braking distance is sufficient between Nos. 2 *and* 3 the sequence of aspects will be

No. 3 at R.

No. 2 at Y.

No. 1 at G, a clear gain of $\frac{1}{2}$-mile unchecked running.

It will be seen that a train can therefore run at speed up to No. 2, being checked by Y at that signal to stop at No. 3. If the previous train has come to a stand just inside that signal, the

two trains could approach much closer than is desirable *although block working is in force.*

This draws attention to a very important fact, namely, that even in manual block territory, where block clearance is a matter for the signalman to govern when applying his standard regulations, it is further necessary to arrange an overlap (which can take the form of an overrun) beyond any signals other than the home signal which are full braking distance apart. This overrun must be based on the formula B—S before referred to, and in conjunction with this an instruction should be given that, in foggy weather, the home signal must be maintained at danger until it is clearly seen that the speed of the train has been reduced.

Where full brake overlaps are provided at each signal as part of the installation the above fogging regulation would not be required.

Diagram 4. In order to provide braking distance between signals Nos. 2 and 3 in diagram 3, it would usually be best to move the starting signal No. 3 far enough forward, track circuit being provided between it and No. 2; but if, due to a level crossing or to a similar cause, the starter cannot so be moved, then it becomes necessary to move back the home and distant signals Nos. 1 and 2 correspondingly.

Diagram 5. Illustrates a case where the distant signal for the next cabin in advance comes on the starting signal No. 3.

It is assumed that there is full braking distance from this distant signal to its relative home signal, but less than braking distance between signals Nos. 2 and 3.

In these circumstances No. 3 becomes a three-aspect signal, but does not carry a marker light (see definition) as it leads to manual block territory.

The sequence of aspects will be as follows:—

No. 3 at R.
No. 2 at R until check contact reached 200 yards from signal, when Y is given.
No. 1 at Y.

No. 3 at Y.
No. 2 at G.
No. 1 at G.

Diagram 6. Illustrates a case where inner and outer distants for the box ahead are fixed respectively on the starter and home signals.

It is assumed that there is full braking distance from the outer distant signal to its relative home signal, but less than braking distance between signals Nos. 2 and 3.

In these circumstances No. 2 becomes a four-aspect signal, the sequence of aspects being as follows :—

No. 3 at R (sequence as diagram 5).

No. 3 at Y.
No. 2 at Y/Y.
No. 1 at G.

Diagram 7. If, as in short section working, there is less than braking distance from the outer distant signal underneath home signal No. 2, diagram 6, an attempt should be made to re-position the signals so as to provide this. Where this cannot be done five-aspect signalling must be introduced, and the sequence is as follows :—

No. 3 at R
No. 2 at Y
No. 1 at Y/Y
} or sequence as diagrams 5 and 6.

These alternatives are determined largely by the actual distance between signals Nos. 2 and 3 and the amount of overlap which can be given beyond No. 3.

No. 3 at Y.
No. 2 at Y/Y.
No. 1 at Y/G.

It will be apparent from the above examples that in applying multiple-aspect signals to interlockings, every effort should be made to arrange their positions braking distance apart. Where this cannot be done braking distance should, as far as possible, be given between alternate signals, in other words, *such signals should always be fixed in relation to braking distance rather than in relation to connections which they may be protecting.*

Passing from Manual Block to Multiple-Aspect Signalling and Vice-Versa.

A number of engineers hold the opinion that the day will soon come when it will be necessary to mark in some way the boundaries of the territory covered by the above distinct systems of signalling, so that a driver can say figuratively that he is stepping from one to the other.

As it has already been pointed out, provided that all signals

are at " proceed " it is immaterial what the system is. Only when a driver is required to slow down or stop is it necessary to indicate to him the system by which he is controlled. The presence or absence of the marker light provides this distinction, as will be shown.

The arrangement is correct in principle, as has been seen :—

Y/R refers to next signal only

Y refers to next signal and any others beyond,

therefore failure of the red light only extends the cautionary control ; in other words, Y/R is " definite," but Y by itself is " indefinite."

It has already been laid down that a marker light shall not be provided on a multiple-aspect signal leading to manual block territory, therefore the following distinction is obtained.

Passing from Manual Block to Multiple-Aspect.

According to circumstances, the cautionary aspect may be separate (figure 1) or combined with the rear M.B. signal (figure 2), see appendix K.

In both cases the presence of the marker light on the trans-position signal is a clear indication that multiple-aspect territory is being entered and that green, when given, has a *definite* value.

An alternative to figure 2 is to fix the cautionary aspect as a colour light unit under a semaphore arm as shown by figure 3.

This, while not so straightforward as figure 2, may enable considerable saving to be made where the top arm is a detected signal, as the existing mechanical detection can remain.

The installation requirements are that when the top arm is " on," the colour light unit is " out." When the top arm is lowered the top red light is blanked out, and the necessary cautionary or clear signal is given by the colour light unit.

A marker light is required to correspond with the arrangement in figures 1 and 2.

Passing from Multiple-Aspect to Manual Block.

In this direction also, according to circumstances, the cautionary aspect may be separate (figure 4) or combined with the rear multiple-aspect signal(s) according to the available braking distance (figure 5).

In both cases the advent of the solitary yellow in the manual block cautionary signal is a clear indication of approach to a two-

aspect "stop" signal, the green indication of which, when given on the train approaching within 200 yards of it, has an *indefinite* value.

Conclusion.

This paper has not been written in any spirit of idealism, as something to be read, commented on, and then laid aside for possible use in the distant future.

On the contrary, it has been written in an endeavour to supply the answers to a large number of problems which are pressing to-day as a result of efforts successfully to apply colour light signalling to the varying conditions met with in railway operation.

The proposals are the result of very considerable study of the problem in its broadest outline, developed as a result of observation during an American trip and applied to British conditions.

They are therefore definite recommendations for immediate adoption, and it is submitted that, if adopted in full, they form a comprehensive and logical policy in the development of "signaling" in its most modern form.

There is no doubt in the writer's mind but that the colour light signal will soon supersede the semaphore as the point is rapidly being approached where it becomes an economic possibility to introduce it in carrying out ordinary renewals. So as soon as this stage is reached the changeover will be very rapid; it is therefore highly desirable and, in fact, essential, that its introduction shall be based on a defined plan which will improve track capacity, considerably increase both efficiency and safety, and also avoid all ambiguity between two differing methods of signalling.

APPENDIX B.

INSTITUTION OF RAILWAY SIGNAL ENGINEERS.

Terms of reference to the Committee on Three-position Signalling, appointed by the Council on March 29th, 1922.

1. To consider and report whether in view of the weight, speed and braking distance of (a) goods trains, (b) express passenger trains, (c) suburban passenger trains, (d) electric passenger trains, any advantage would be gained by the adoption of a third indication obtainable by a system of three-position signalling.

2. To consider and define the most suitable aspects of three-position signals as applied to through running traffic (e) by day, (f) by night, in order to indicate unmistakably the exact condition of the next signal ahead without possibility of being interpreted in a less restrictive manner than intended.

3. To consider and define the most suitable aspects of three-position signals as applied to diverging movements at junctions (g) by day, (h) by night, in order to indicate unmistakably the geographical direction of the route set up—the speed to be observed—without possibility of being interpreted in a less restrictive manner than intended.

4. To consider and report whether the indications should be given by the relative position of arms in a horizontal group (on separate posts) or by arms placed one above the other in a vertical group (on the same post).

APPENDIX D.

MINISTRY OF TRANSPORT REQUIREMENTS (1928).

Extracts relative to signalling which are referred to or are modified by the recommendations of report.

At diverging junctions, one "distant" signal only should be provided, worked for the junction line over which the highest speed is permissible, unless in exceptional circumstances more are essential.

Where special circumstances, *e.g.*, permanent speed restriction, justify the adoption of an unworked signal, it should be secured in the warning position and not coupled up or duplicated for directing purposes.

At diverging junctions, a separate running signal will be necessary for each direction of movement.

At diverging junctions, bracket signals are preferred to signals carried on separate posts, unless there are reasons to the contrary.

A special type of shunting signal for wrong line movement is not considered necessary. In cases where it is not possible to turn the movement in the right direction on to a running line by reversing a cross-over, or on to a siding by reversing the points an indication, visible by night and day, of the limit of such movement will meet the case.

With semaphore signalling, indications for "calling-on" movements to be given by a small arm carried under the relative "stop" arm. By night, a white light to be shown in normal position, and the light authorising the "calling-on" movement to be green. "Calling-on" signals to be used only for the specific purpose of indicating to a driver, either that the line between the "calling on" signal and the next "stop" signal (or buffer stop, when there is no "stop" signal in advance) is occupied, or that he is required to stop for instructions at the signal box ahead.

"Stop" signals when working automatically under the "stop and proceed" regulation should be distinguished by the letter "A." In the case of controlled signals, when working automatically the letter "A" should be visible both by night and by day, and should be obscured when the "stop and proceed" regulation does not apply.

Light signals of an approved type should be used, in place of semaphores, for three- or more aspect signalling. They may also be used for two-aspect signalling.

Front lights of all running signals to be red for danger, yellow for caution (including the warning position of "distant" signals), and green for clear.

For two-position shunting signals, the normal light indication may be either red or yellow. The red light to be used only when it is necessary to indicate that the signal is not to be passed without special permission, unless it is in the "clear" position. In other cases yellow to be used. In the case of shunt ahead signals, etc., carried under running arms, the lights used to be the same as those for "calling-on" signals, with lettering as necessary.

The arms of all stop signals, and the "danger" or "on" aspect exhibited by all light signals, which cannot readily be seen by the signalman, and the arms of all "distant" signals, to be repeated in the signal-box from which they are worked. It is desirable that the lights of all semaphore "stop" and "distant" signals upon important lines with high speed traffic, should be repeated, unless either the front or back lights can readily be seen from an adjacent signal-box.

A red light to be used by night to define the position of buffer stops at the termination of platform arrival lines.

INTRODUCTORY REMARKS.

The **Chairman**, at the opening of the meeting, on behalf of the members of the Institute of Transport, offered a hearty welcome to the members of the Institution of Railway Signal Engineers, and, in particular, to Mr. C. Carslake their President. It was a happy suggestion that the two bodies, which were interested in common in matters such as signalling, should meet together and pool the experience of those who were primarily concerned with signalling in its technical aspects with that of those who perhaps had to suffer under signalling in its practical aspects as railwaymen.

The discussion that evening was to be introduced by a paper by Mr. A. F. Bound, the Signalling Engineer to the London, Midland and Scottish Railway, who occupied the most eminent

position which could be attained by any railway signal engineer in this country, being directly responsible for the signalling of the London, Midland and Scottish Railway.

The present was perhaps a particularly opportune time to discuss the subject, since signalling was passing through a stage of transition from the old-fashioned types of signal to the new, and when there were many problems which needed consideration and—which was even more difficult than consideration—needed prompt decision. Mr. Bound brought forward in his paper many problems which needed immediate decision in order that standards might be adopted for use and development in conjunction with the English railway systems.

At the outset, however, Mr. Pick humorously observed that he wished to dissociate himself from the paper, because he had looked at it as an Underground man and he found that the Underground system was swept aside with a few very curt and brief references. Mr. Bound seemed to think that all that was necessary on the Underground system was a simple one-light arrangement with red for stop and green for go, whereas even Oxford Street had a yellow cautionary light!

DISCUSSION.

The Chairman **(Mr. Frank Pick),** said the Author had described his paper as but a stage towards the development of a final system of signalling, and it was valuable to see how, stage by stage, progress was made from simple to complex and then once more, as things settled down, from complex to simple, because in the end a signalling system must become something quite simple and be readily understandable even by those who were not conversant with its technical details.

He thanked the Author for the pains he had taken in preparing the paper so that all might share in the experience which came to those who were fortunate in being placed in positions of responsibility in having to carry forward the development of signalling. Personally, he did not propose to venture on any criticisms of or comments on the paper, since he was unable to proceed in those technical fields with safety;

but it gave him great pleasure to propose a vote of thanks to the Author, which he would ask Mr. Carslake to second.

Mr. C. Carslake, President of the Institution of Railway Signal Engineers, in seconding the vote of thanks described the paper as the finest treatise on multiple-aspect signalling which had yet been produced. It was of particular interest to him personally because in his recent Presidential Address he had definitely referred to the desirability of tabulating recommendations as to the lines on which colour light signalling should develop in this country and he had suggested that the Institution of Railway Signal Engineers—which prepared the original report on three position signalling—was a fitting body to formulate the more ambitious proposals.

The Author's contribution would be a valuable addition to the Proceedings of the Institute of Transport and of the Institution of Railway Signal Engineers for the reason that it contained concrete proposals for dealing with practically every railway signalling condition that was likely to be met in this country.

In 1915 Mr. Bound had read a paper before the Institution of Railway Signal Engineers entitled, "A review of the art of signalling and some suggestions." At that time it had not only created a great deal of discussion and some controversy, but it had been necessary to have two meetings to deal with it fully. Some of the suggestions he then put forward were regarded as revolutionary but to-day they were commonplace practice. It was quite probable that the proposals outlined in this second paper would be standard practice in a few years time.

The present joint meeting was the first of its kind, but it was obviously so successful that he sincerely hoped further meetings of the two bodies would be held in future.

The vote of thanks was then put and carried with acclamation.

Colonel A. H. L. Mount opening the discussion said he had heard it whispered that he was expected to launch out on a criticism of the Author's proposals, but railway officers would know that he never criticised. He had certain opinions which he endeavoured to ventilate or impress on others, but he would not cross swords with any of the eminent signal engineers present whose skill and efficiency he appreciated.

It was in that light that he viewed the valuable paper presented by Mr. Bound. It was obviously the result of the Author's

experiences in America, and it set out clearly his apparent intentions. There were many controversial points in the paper, but it came at an opportune time. While he did not propose to be controversial, he joined issue with the Author's implied criticism in the passage which read: "This is where the Americans have been fortunate, as they are not hampered by tradition nor have they the conservatism of the British." Later in the paper, the Author complained that the older school of thought had had matters much too much their own way. He (the speaker) doubted whether we in this country really had a great deal to learn from other countries, where conditions were very different. We should be wise if we worked out our own salvation. While anxious to be receptive of new ideas, he hoped those concerned with signalling would remain, if not conservative, at any rate true to their traditions, which had surely been simplicity first and foremost, the primary consideration being "What does the driver want to know to enable him to run at maximum applicable speed?" Further, "What is the safest, most efficient, least confusing and cheapest way of giving him the message he requires?"

He expressed his agreement with the Author's opening statement, namely, that one of the most pressing needs in the modern signalling world appeared to be some greater co-ordination. There was no doubt that the time was rapidly approaching when a discussion should be initiated by the four main line companies with a view to obtaining uniformity of principles and an adequate degree of standardisation of colour light codes in multiple-aspect signalling. As was said in the very apposite remark by Mr. Rudd, of the Pennsylvania Railroad, which was quoted in the paper, "a given signal aspect must transmit the same information at all times, at all places, and under all conditions." He thought it would be agreed that that was of fundamental importance.

Mr. W. Challis said the President of the Institute of Transport had referred to the fact that the Author passed over very quickly the signalling on the Underground Railways. Personally, he would go a step further and say the Author had also passed over all the railway signalling in this country!

The Author had referred to the fact that in 1923 the Great Central Railway installed three-aspect signalling between Marylebone and Neasden. He believed that had given entire satisfaction. It was deliberated upon by the Committee on

Three-position Signalling, and, as there were four members on that Committee who had large experience on the Underground Railways, it might be said that three-aspect signalling was built up primarily from two-aspect signalling, namely, a repeater signal under each stop signal in the rear; it was in effect three-aspect signalling.

When referring to Appendix E, diagram 2, the Author had stated that the red aspect of the repeater would never be seen by the driver in normal working, but that a red aspect would be shown when approached after a driver had passed a rear stop signal under the one-minute or other time rule; yet on the right hand side of that diagram the Author gave a three-aspect signal showing a single yellow and the two-aspect a red. He asked for a further explanation on that point as it might be he had not understood the diagram. The diagram gave 1,700 yards between each three-aspect signal, and the Author claimed that, with a two-aspect repeater signal 700 yards ahead of the three-aspect, the driver could proceed unchecked an additional 700 yards; he had also stated that 1,000 yards could be taken as an absolute overlap. If that were so, then with three-aspect signals placed 1,000 yards apart, 6 signals would be required in the distance in question, which would total 18 aspects, while the Author's scheme required 20 aspects, and if the speaker understood the position correctly the capacity of the line would not be as much under the Author's scheme as under the other.

On March 21st, 1926, the Southern Railway installed four-aspect signalling from Holborn to Elephant and Castle, and on June 27th of the same year between Charing Cross, Cannon Street and Borough Market, and subsequently a vast signalling installation at London Bridge, all with four-aspect signalling, and later again to New Cross and St. John's; further, the company was installing three and four-aspect signals mixed up together for another hundred track miles. He suggested that the knowledge the Southern Railway officers and enginemen had obtained in those six years, proved that a good system of signalling had been provided.

The Author had also recommended a complete overlap. That might be efficacious where train control existed. The Author had mentioned that a driver might miss a light, and on reaching the next signal find it at red, and had suggested that the driver should have an overlap sufficient for him to pull up when

travelling at his highest rate of speed. He (the speaker) thought that if the driver missed one signal he might miss the next one, and he did not believe an absolute overlap was of any use whatever unless there was complete train control, or at least a warning.

He agreed with the Author's contention that arms should be retained on manual worked signals; that practice would be of great help as a distinguishing mark between multiple-aspect signals and manual signals. At the same time there might be cases, as had happened once or twice in his experience, where there was not room to put a semaphore arm, as for instance under a bridge.

Mr. F. Bushrod said he regarded the paper as very valuable, in that it set out present practice in this country and modern practice in America, and thus gave a starting point from which it was possible to build up in the future. There could be no question that colour light signalling had come to stay. Whether that colour light signalling was of the three, four or five aspect type was a matter for the future, but speaking from his experience as a traffic man, and of three and four colour light aspects, he could not see that any case had been made out for anything beyond four aspects. The Author might be right in advocating five, but it would be interesting to have some illustration of the need which called forth the five-aspect system in America.

With respect to speed signalling, to which the Author had directed attention, the speaker could not profess to have read the paper so carefully or to have studied the question of speed signalling so closely as to be able to speak conclusively as to its value. At first blush it struck one as somewhat complex. It would be of interest to hear from the Author as to its value in America; certainly at first sight its value was not apparent.

The Author had referred to the line of demarcation between the present mechanical systems and colour light systems, and he (the speaker) agreed that sooner or later that problem would need to be solved. Whether the marker light was the right way of dealing with it might be questioned, because it would be seen from the appropriate diagram that when the colour light was green the marker light disappeared, which seemed to him to be extraordinary; it meant that, in the case of restrictive lights, the driver was given an indication of the type of signal he was approaching, but when he was given an unrestricted signal

that indication was not afforded; yet to a traffic officer that was the only time when it was wanted.

He would like to express the hope that, as a result of the present meeting, an opportunity for further discussion would be afforded, possibly in a more restricted area, because it was obvious that so vast a problem required very close application. He felt that, following the submission of the paper, it might be possible to see more daylight on all the problems which it presented, and from that point of view the Author was to be congratulated on the close attention he had given to the subject and on the food for thought he had provided.

Mr. A. Moss said the Author undoubtedly had given all those concerned with railway signalling much to think about; whilst there were many points upon which it was impossible to disagree there were certain features upon which opinion might not be unanimous. It was vitally necessary to distinguish between colour light signals used in manual block territory and multiple-aspect territory. The practice of replacing mechanically operated signals by colour light signals in difficult locations was becoming more frequent and any extension of multiple-aspect signalling in proximity thereto was almost sure to lead to misunderstanding unless some means of differentiation were adopted.

The Author had expressed the view that approach lighting would be the means of enabling colour light signals to be adopted more widely in the future. In certain instances that might be so, but it must not be overlooked that the maximum benefit to be derived from approach lighting was dependent upon an infrequent service of trains. In such cases there would appear to be no necessity to alter the signalling on the score of increasing line capacity; therefore, the cost entailed in installing an approach lighted colour light signal would have to be set against the bare cost of renewing the existing arrangement, and this might not be found in practice to be so remunerative as was anticipated.

On the suggested arrangement of protective controlled colour light signals the Author seemed to have departed, in certain conditions, from the principle of a fouling movement having the protection of two red indications. The speaker considered that for uniformity it might be advantageous always to adopt the principle outlined in diagram 8, Appendix E, sheet 2, the controls being varied in accordance with the type of block in use.

Under this arrangement, all junctions would have "free" acceptance at all times, the only variant being that, during fog trains would need to be kept at the outer signal No. 2. The proposal to use detonator placers in conjuction with isolated colour light distant signals raised the question of the replacement of the detonator when a lamp had failed and the apparatus had functioned. Cases were not unknown of the apparatus being minus the detonator, in which contingency the warning would not be available.

He considered the Author said some very hard things about the antagonists of speed signalling; hitherto the protagonists had never put forward a scheme wholly acceptable. Now, however, the Author "sugared the pill" by combining routing with speed indications and thereby eliminated the main objections previously held against "speed" signalling.

The examples given in Appendix F, diagrams 1 to 4, showed very clearly the general application of the principle, although diagram 1 appeared to require amendment to obviate a high speed "green" indication leading up to a "red" indication.

Mr. G. H. Crook said the members of the Institution of Railway Signal Engineers, at all events, knew exactly what his opinions were on the subject under discussion. He wished to congratulate the Author on his great achievement in trying to set out the anomalies, the inconsistencies and the limitations of some of the present systems and to reduce them to a sane and logical order. It was a formidable task, and the Author had rendered the signalling world, and indeed the railway world in general, a great service.

One or two speakers had already referred in some detail to the great bogey of the line of demarcation between the two systems. He had had some ten or eleven years' practical experience on speed signalling, and he was inclined to think, in the words of an old saying, that an ounce of practice was worth a ton of theory. When speed signalling was introduced on the line with which he was associated, there were exhibited notice boards inscribed "Entering Three-Position Territory" and "Entering Two-Position Territory." Ultimately those boards became very dirty and illegible, and the traffic and locomotive departments were asked whether they should be repainted; the answer was "No, take them away."

The position he took up was that the first thought should be for the drivers, and anything that could be done to help them was the primary duty of signal engineers. The driver's work had become much more onerous in recent years, with longer journeys, heavier trains and higher speeds, but worst of all the aspects at junctions and other places tended, with the expansion of railway facilities, to become more complicated. From that point of view he had every sympathy with the Author in his efforts towards simplification.

It would take too long to comment on the details of the scheme. The paper needed thorough study and, although he had no great liking for committees, he hoped facilities would be provided for the further consideration of the paper.

He had been amused by what the Author had said about the Committee on Three-position Signalling. He believed that apart from the gentleman who signed the minority report, he was the only one who had had the courage to say anything against it.

He did not wish the Author to regard his remarks as other than highly complimentary. Personally, he disliked the term "multiple aspect"; he thought it was simply an eye and ear catching term, and a complete misnomer. What really was intended was "progressive" signalling. Multiple aspects had always existed; the bugbear of the system had been multiplicity of aspects. One had only to go to Piccadilly Circus to see multiple aspects.

He thought the Author had had a little difficulty in trying to circumvent that contradictory aspect of red over yellow. It was most unfortunate; it seemed to him to be one of the legacies handed down as the result of an unbalanced psychological period which followed soon after the war. The aspect was radically wrong. There were two lights; one indicated "Stop" and the other said "Go". The change to the yellow light was correct and defensible in regard to the isolated distant signal, but should never have been carried out in regard to combined home and distant signals. He thought it was quite wrong, and much money had been wasted in making that change.

When referring to marker lights, the Author had mentioned the one or two minute rule. The marker light apparently signified a permissive aspect and allowed the driver to pass after a stop of one or two minutes. He asked, why one or two

minutes? Why not stop and then proceed? How the driver did count one or two minutes? It was not a matter of time; if he stopped, that was sufficient. He (the speaker) would be more revolutionary.

The Author had also had to face that most difficult question of fog and fog working. There was only one solution for that, namely, automatic train control in some form or other.

Using the Author's own term of multiple-aspect signalling, it really amounted to a more equal splitting up of the block sections, giving equal space, or rather, in modern language, equal times. It was often possible to learn something from some of the older sciences, and a rather interesting and beautiful parallel occurred to him from the realm of music. In the old world scales, the progressions from one tone to another were very erratic. One of those old scales, as a matter of fact, dated from the time of Pythagoras, about B.C. 500. This was continued, among others, for very many years, and it made orchestration very difficult in remote keys in consequence of the unequal intervals. Bach, who was both a mathematician and a musician, solved the problem by making these tone intervals of equal value. That was exactly what the Author was trying to do with multiple-aspect signalling.

With respect to the speed signalling of junctions, in the case of a junction with three converging lines there might be a normal speed of anything up to 90 or 100 miles an hour, if the locomotive could do it, and there would be a green light. The signal for a train coming off the branch at 25 miles an hour would show a green light, and the signal for a train coming out of a siding at 10 miles an hour showed a green light. They all showed the same green light. The great advantage of a speed signalling system of the character the Author had described was that for all those converging movements there would be a fairly definite speed value indicated to the driver, and the speaker thought that was of very great value.

In the case of distant signals, it did seem somewhat illogical to give the driver information regarding divergence at a mile away from the junction point. The problem was further complicated where there were one or more home signals intervening between the splitting distants and the actual junction, because first one had a directional signal, then a unidirectional signal, then perhaps another unidirectional signal and then a splitting

signal which was directional. The whole situation was complicated but he believed it could be simplified under the system of signalling proposed.

Even speed signallers were likely to look at the same subject differently, and as the Author had been to America recently it was possible he was a little more up-to-date than the speaker could claim to be. Naturally, after some years on route signalling one tended to become a route signaller, in the letter if not in the spirit. He wished the Author success in the effort on which he had embarked and, as he had gone practically 90 per cent. of the way to the speed signaller's heaven, he hoped he would ultimately reach it.

Mr. W. Wood said that whatever might be the concensus of opinion about the ethics of the paper, he thought electrical engineers would agree that it was possible to equip all the aspects electrically; the circuits—complicated as they were—were quite practicable and safe and reliable results could be obtained.

One point concerned the availability of electricity at the present time. No doubt the Author had worked out in his own mind how he would be able to obtain the necessary power for his signals, and it was to be noted that he had very cleverly restricted the aspects in areas where a cheap and abundant supply of electricity was not obtainable. The grid and its interconnectors could not help for a very long time and, as main line traction was hanging fire, and it might be some while before it was an accomplished fact, there was not the advantage of electricity alongside the track to tap in for the signalling arrangements.

It would help the Author's scheme if he could be sure of an abundant supply of electricity at his various locations, and he had rightly had recourse to what was known as approach lighting from primary batteries. They were economically sound and were working successfully. But primary battery maintenance was very high, and in the working out of part of the scheme in question, he wondered whether the modern innovation of small petrol units of, say, $\frac{1}{2}$-h.p., giving about 120 watts, was not a very much cheaper proposition than primary batteries. The cost per unit of primary batteries at a large number of these locations was high and averaged about fifteen shillings. Petrol sets, on the other hand, could be started by maintenance men and knocked off automatically; they had always the accumu-

lator as a standby, and seemed astonishingly cheap in maintenance. They were used largely by the Post Office.

Mr. C. R. Byrom said the necessity for and value of the paper was bound up in the last paragraph, which read: "the colour light signal will soon supersede the semaphore, as the point is rapidly being approached where it becomes an economic possibility to introduce it in carrying out ordinary renewals. So soon as this stage is reached the changeover will be very rapid; it is therefore highly desirable and, in fact, essential, that its introduction shall be based on a defined plan."

As a traffic officer, he desired emphatically to express the view that, in the interests of the railway companies of this country, it was essential that traffic officers and signal engineers should at once draw up an agreed standard system for what he would still call multiple-aspect signalling.

There were many points in the paper which might be controversial, but it contained the basis of a sound standard system of multiple-aspect signalling, to go no further than that. He was satisfied that agreement could be reached on these controversial points.

Speed signalling was a subject which should be given the most earnest attention and progress should be made with it so far as it was possible to do so. It was undesirable to be too conservative in this country or to think it necessary to go to any particular country for ideas.

The railways had a great deal to gain from the introduction generally of a colour light system of signalling; the use of such signalling in fog would render possible the withdrawal of fog signalmen when traffic officers were satisfied as to the penetrating power of the light signals. Careful consideration would need to be given by traffic officers to the question of overlaps.

The **Chairman** said the President of the Institution of Railway Signal Engineers had intimated to him that he thought a further discussion in the more restricted field to which one speaker had referred was desirable, and he would welcome to the meeting of the Institution of Railway Signal Engineers at which that discussion would take place any traffic officers belonging to the Institute of Transport who would like to attend and take part.

As a layman, he did not care to take part in the discussion, but he had been thinking that a simple system of signalling

would be a series of single lamps ; green : proceed, two blocks ahead clear ; yellow : caution, one block ahead clear ; and red : stop—a one-light indication with three aspects. If it were desired to go a stage further and have two lights, a double indication, that would necessarily give five aspects, and he believed a logical sequence there would be :—two greens : four blocks ahead clear ; green over yellow : three blocks ahead clear ; two yellows : two ; yellow over red : one ; two reds : stop. That seemed to him perfectly simple and logical, and he could not understand why any confusion should arise ; so he was tempted, with all respect to signal engineers, to suggest that, as a logical solution of the five-aspect signalling problem, both systems gave a uniform spatial indication. All that was required was to define what was a " block " or the minimum distance between signals. Without any change in indication the five-aspect signalling system enabled the driver to judge his proper speed—for green obviously permitted full speed by reason of the considerable space ahead that was clear. Yellow permitted only a checked speed and as soon as red appeared a still more checked speed. The five-aspect signalling system could be adapted to institute a check on speed at junctions, or even to establish temporary speed checks on running lines by a kind of syncopation which cut out the green. There could be little doubt that it represented a step in progress of importance and significance, and Mr. Bound was to be congratulated on bringing it so lucidly and fully before the meeting.

COMMUNICATED DISCUSSION.

Mr. H. C. Walter : Some comments may be made on the question of " speed " signalling. Past practice in this country has been in the direction of " route " signalling—as witness the complicated forests of posts and semaphore arms at big junctions—and this has been carried back to the distant signal position, providing at that point as many arms as there were at the actual junction. But in recent years, the custom has been to provide only one distant signal, which has been operated for the fast-running route but has been incapable of operation for diverging lines—thus, to an extent, the principle of " speed " signalling has been admitted.

At present entire responsibility is placed upon drivers—and will be for many years to come ; for that reason they are expected to know every inch of the road, by day or by night. Fixed signals are a means of indicating to them the condition ahead ; the information having been provided, it is the driver's duty to control the running of his train accordingly. If the driver is told on what route he is to run (by means of " route " signalling), he may justifiably be expected to do the rest. If he is given only a " speed " indication—admittedly vague—it seems that the enginemen are not receiving all possible help. It may be suggested, then, that " speed " signalling is essentially wrong.

The introduction of colour light signalling seems to give a wonderful opportunity for abolishing the necessity for a driver passing at speed (as opposed to a calling-on or shunting movement) a danger indication applicable to the road on which he finds himself. Where speeds are slow, as when entering a terminal station, the principle has been adopted of putting but one signal for each line, coupled with a route indicator to shew which platform road is to be used.

It would appear that very much the same thing should be done for a high-speed running movement, using therefor two or three " moonlight-white " lights, according to the number of routes, placed in a horizontal row. The colour is used on the French State Railways, I believe. These route-lights should apply according to the route to be used—the left-hand light for the left-hand route, and so on—and should illuminate only in combination with a yellow or green signal indication, whilst the feed to the signal indication should pass through the route-light. Thus, in case of danger, a driver would see only one red light applicable to his line. For " caution " or " clear " he would of necessity have both the signal-indication and the route-indication ; or, in the case of light failure, nothing at all, as at present ; this failure would of course, as at present, be repeated in the signal box.

If it is considered essential to give the driver further warning of his diversion, this could be arranged—as it is now in certain cases—by controlling the " clear " indication by means of a short approach track-circuit.

It is suggested that the above system would have the advantages of simplicity, of cheapness (as compared with the system outlined by Mr. Bound), and of giving the driver full

information as to what is to happen to his train, whilst leaving him to use his own intelligence according to circumstances and having regard to any standing instructions at the point concerned. The Ministry of Transport Requirements touch on this matter.

THE AUTHOR'S REPLY.

The **Author,** in reply, said it might well be that an apology was due to Mr. Pick for the fact that, in Appendix C, the Underground Railways had been dismissed with a red and a green light; personally he had intended that should be regarded as a great compliment, because if he had attempted to describe fully all that they did for the speedy and safe working of traffic there would have been little room for anything else in the paper; he claimed, therefore, to have taken the only course possible by disposing of the Underground Railways quickly and so leave him to develop the subject of aspects for mixed traffic operation.

Although Col. Mount intimated that he would not criticise the paper, he had challenged the criticism therein of British conservatism. He (the Author) was definitely of the opinion that this conservatism had, to some extent, hampered progress and, whilst agreeing that we in this country had not a great deal to learn from other countries, we should nevertheless be receptive of their ideas, profit by their mistakes, and be prepared to adapt and adopt anything that appeared to offer definite advantages.

He trusted the apology he had already made to Mr. Pick would satisfy Mr. Challis, who also had taken him to task for his scanty reference to the Underground Railways, but it was certainly inaccurate to say he had passed over all the signalling in this country, seeing that every known aspect came directly or indirectly under review.

With reference to Appendix E., diagram 1 showed the cautionary aspect 1,700 yds. plus the overlap to the rear of the train, whilst in diagram 2 the corresponding signal was at green, the cautionary aspect being 700 yds. plus overlap from the obstruction, hence the claim for an additional 1,000 yds. unchecked running.

He was not aware of any statement that 1,000 yds. could be taken as an absolute overlap and the speaker's remarks

appeared to show a misapprehension of the Author's intentions.

The Southern Railway had every reason to be proud of their three and four aspect colour light system, the main variation suggested by the paper is the addition of the marker light.

Mr. Bushrod was a traffic officer for whose wide knowledge of railway operating the Author had the greatest respect. Mr. Bushrod said there had been no case up to the present on the Southern Railway of multiple aspect colour light signalling calling for more than four aspects.

He (the Author) thought conditions were such generally that five aspect signalling would be a rarity, but after all it was entirely a question of braking distance and just as it was found, in the early days of three aspect signalling in this country, that the situation of the Y did not always afford sufficient braking distance and so called for a fourth aspect Y/Y, so it may be found, as the application develops, that the situation of the Y/Y may not invariably provide adequate braking distance for trains travelling at the highest speeds; therefore, in laying out a complete system of signalling, it is necessary to take into account all the possibilities which may occur.

In regard to the proposal that the marker light should go out when the signal shows green, he had tried to make his view clear although it was not easy to do so.

Throughout the system no lights are shown that do not fulfil a useful and definite purpose. If all signals were at green on, say, a journey from Waterloo to Southampton what help would it be to a driver to tell him which was manual block and which was multiple aspect territory? They all mean the same thing, namely, "proceed," and with this knowledge all a driver needs to know additionally is which stations he is to stop at, and the location of various permanent speed restrictions.

It is not until he has to slow down by signal indication Y, or stop by indication R, that it becomes necessary for a driver to know the type of signal he is obeying, and then it is clearly denoted by Y/O or Y/R leading up to R/O or R/R, the former indicating a distant signal just as it does to-day calling for the operation of Rule 40 at the home signal, which when turned to green *does not* mean next signal "off," whereas the latter indicates a multiple aspect signal ahead which if turned to green *does* mean next signal "off."

The psychological effect of keeping the red up when the

aspect is green would be bad and it must be remembered that to many of the older drivers this combination instinctively means home " off " distant " on."

He (the Author) was very glad to note that Mr. Bushrod agreed that sooner or later the problem of demarcation would need to be solved, therefore the earlier this was attempted the better.

He was pleased to hear the following speaker, Mr. Moss, say he also was of this opinion.

He would like to emphasize the fact that the question of approach lighting was entirely one of economics and once its application and possibilities were accepted, no other factor need be taken into account ; further, colour light signals of any type would not be introduced unless there was every good reason for the installation and then it would be incumbent upon the Signal Engineer to provide his railway with maximum facilities at minimum cost.

He was not aware of any definite principle of a fouling movement having the protection of two red aspects, especially in colour light territory, but he submitted that having regard to the differing conditions between clear and foggy weather, this condition was met in the latter case, whilst giving flexibility of operation in the former.

With reference to the detonator placer, he could only say that if it was properly looked after it might reasonably be hoped that, when the time came for it to be used, the detonator would be in the machine. A driver exploding one, due to the light being out, would stop and report the matter at the signal cabin and, until replaced and the light restored, the relative rules would apply in the case of following trains.

He was indebted to Mr. Moss for calling attention to the obvious error in Appendix F. diagram 1, where, in the first example, Y instead of G should lead to signal D at R.

He certainly had looked to Mr. Crook for support and very much appreciated the remarks he had made. He agreed with Mr. Crook's criticism of the term " multiple aspect " which was probably due to the fact that the average Englishman was not too particular in the nomenclature which he used. No doubt the term " progressive aspect signalling " would give a very much better idea of the aim of a system of signalling of the character under discussion. He was glad to note Mr. Crook's

comment relative to the present aspect R/Y; it afforded an example of how one might easily strain at a gnat and swallow a camel; if such a thing had been suggested in the paper, it might conceivably have caused a riot.

On the subject of the one minute rule, he was of the opinion that some such time interval was desirable as without it there would be a tendency for drivers not to bring their trains actually to a stand and the "stop" aspect might consequently lose its significance; further, the obligatory pause provided a margin for the line ahead to clear.

Mr. Crook referred to speed signalling of junctions relative to "converging" as distinct from "diverging" movements. No attempt had been made to provide for such cases as the speed reduction necessary is a permanent one and as such does not call for signal indication. If anything is needed an illuminated speed lamp is the solution.

He wished to emphasize that speed restrictions come under two categories: (*a*) permanent, (*b*) occasional. An example of the first is a bad curve in a given length of line—knowledge as to the position of all such restrictive places and the relative speeds is part of a driver's stock-in-trade. The second is an entirely different matter as its incidence rests with a signalman's action and may give rise to a necessary restriction quite unexpected by a driver and, for this reason, signal indication and protection are necessary and speed signalling forms a highly effective means for providing them.

Mr. Wood had laid his finger on one of the main difficulties in the present application of colour light signals. It may be said, however, that the need for such signalling is generally greatest in the vicinity of the larger towns and there electrical supplies are usually available. He (the Author) felt, therefore, that this difficulty was not really so great as might appear at first sight, especially bearing in mind the possible application of small petrol units as suggested by Mr. Wood.

He thanked Mr. Byrom, who was a colleague of his, for his support because Signal Engineers were really the servants of the operating department and those in charge of operation had to be satisfied that any new ideas were in the best interests of railway working generally. Too great a degree of conservatism was undesirable and he hoped with such support it would be possible for the railways to come together in common agreement.

The Americans had built up their signalling largely on British practice, but naturally with their vast territory and with their lack of co-ordination, which appeared to be even greater in America than in this country, the result was, as would be seen in Appendix A, varying systems comprising colour light, position light, and colour position light signalling, all differing in aspect, and that was a position we in this country must avoid.

If the paper were studied it would be found that only a very small portion of what was done in America had been selected as suitable for application to British conditions.

He thanked Mr. Pick for the description he gave of his ideal three and five aspect systems. The former was on all fours with the three aspect systems generally in use to-day and the latter agreed with the Author's proposals with the exception of the G/G and G/Y. With all respect to Mr. Pick he could not see that the duplicate G was of any greater value than a single G; he submitted that drivers running on "proceed" signals did not evaluate their position in terms of "blocks" that did not arise until a cautionary signal was encountered. He had already dealt at length in the paper with the objections to the aspect G/Y and would not therefore go over the same ground again. He trusted that following this brief explanation he could feel he had another supporter in the President of the Institute of Transport.

In conclusion he thanked his audience for the kind attention that had been given to his paper.

General Meeting of the Institution

HELD AT

The Institution of Electrical Engineers,

Wednesday 4th, April, 1932.

The President (Mr. C. CARSLAKE) in the Chair.

The Minutes of the last meeting having been read and confirmed and Messrs. A. C. Alexander and S. M. Taylor, members present for the first time, having been introduced to the meeting: The **President** said that, as all were aware, circumstances over which they had no control, prevented members from thoroughly digesting the paper read at the Joint Meeting on March 14th, before it was presented. It was felt that their own Members should be given a further opportunity to present their views and the meeting that evening was for that purpose.

In calling upon the Author, the **President** added that the more one read the paper the more one was struck by the vast amount of care and thought put into it and the manner in which the proposals were set out in the diagrams.

RESUMED DISCUSSION.

Major R. Falshaw Morkill believed that he was voicing the opinion of all Signal Engineers in this country when he stated that the subject covered by the paper had given them serious food for thought. He was whole-heartedly with the suggestion made by the opening remarks wherein greater co-ordination in the development of colour light signalling schemes was called for.

The following were directly interested in signalling matters:—the Traffic Department, the Locomotive Department, and the Signal Engineer. It was essential, therefore, that those three sections should get together for the purpose of co-ordination and, in his opinion, the following were the principle features to be considered: (*a*) Types and aspects of signals; (*b*) Costs. With regard to (*a*), the system should be as simple as possible. Signals should be so arranged that they could, without any mistake, be easily picked out by drivers; the messages they conveyed must be clear and distinct; frills should be avoided as much as possible.

Referring to (*b*), a great deal depended upon the cost, as, to a considerable extent, it influenced the amount of new work and improvements which could be carried out. Obviously, the more complicated the system the higher the cost and that might be such as to seriously retard progress. But there was also another phase in a complicated system which must not be lost sight of and that was the higher cost of operating and maintaining it; to say nothing of the possibility of more frequent failures with consequent delays to traffic. They should, therefore, aim at developing a consistent system of signalling, which was simple in character and which could be installed at a reasonable low cost, with low operating charges and be easy to maintain.

The Author, in his very excellent paper, had given a lead in that direction. The Speaker was in accord with many of the suggestions made, with, perhaps, some simple modifications. He approved of the reference to two-aspect signalling as applicable to underground railways. Marker lights were essential, but he was not entirely satisfied that red was the correct, or most desirable, colour. There must be a distinguishing badge for indicating stop-and-proceed automatic signals from stop-and-stay controlled ones. He did not think the off-set of 10-in. proposed was sufficient.

For colour light shunt signals he would choose the aspects of red and yellow; for calling-on signals the banner type had his preference. The provision for winding-off a train stop by a time element relay was clever; it was perhaps a rather expensive frill and he was not at all sure that it was an entirely desirable feature.

It was certainly important that colour light signalling aspects should be standardised, and no time should be lost in providing the necessary machinery for bringing that about–a duty which he considered lay with the Institution of Railway Signal Engineers. He joined with others in offering his sincere congratulations to the Author.

The Author's reply to Major Morkill.

I must first of all thank Major Morkill for his remarks and I am glad to know that he has no criticisms of a destructive nature to offer to my proposals.

With regard to the colour of the marker light, choice is limited by the fundamental necessity that any failure of the top light must not result in a less restrictive aspect, therefore only

red or white is available. The former is to be preferred as being less likely to be confused with extraneous lights and is also free of the possibility of being mistaken for green, the latter is likely with white under certain conditions, *e.g.*, if a driver has been gazing into the firebox. Red is also a valuable aid to a driver in correctly appraising a yellow as distinct from a red top light. Experience shows that without the red marker such mistakes are possible.

Major Morkill refers to the time-controlled permissive marker light as a frill. I hardly regard it as such on any line with an intensive service where train stops are provided. It obviates passing signals in the " danger " position and also avoids the delay and annoyance inseparable from the action of the " trip " application at slow speed.

Mr. S. L. Glenn considered that it might be said that the Author's ideas were summed up in the sheet of signal aspects given in appendix G, which showed all the aspects required to give effect to those suggestions. The sequence of aspects and the simplicity of the system would perhaps have been more readily grasped if the progression of aspects on that and other sheets had been reversed. The sheets would then have illustrated the normal progression seen by the driver running at high speed under green being cautioned by yellow and finally called upon to stop by red.

Turning to the Proposed Standard Signal Aspects shown in appendix G, he did not think that anyone could object to those for the Straight Line shown in the first row except, perhaps, in regard to the necessity or otherwise for the provision of marker lights and, if provided, their colour. His own preference was for red, and he was in agreement with the Author in that respect for the reasons he had just given in answer to Major Morkill. The two reds in the " danger " aspect were most arresting and particularly useful in foggy conditions. He was not, though, in favour of cutting out the marker light entirely when showing the green aspect; he would rather dim the marker light under those conditions and so preserve the form of the signal whatever aspect it displayed.

The special signals were all good except the splitting distants. He was not in love with splitting distants and would delete them, using instead the vertically arranged signal. If splitting distant signals had to be provided, it might be better to show

red instead of yellow in the small outside directing lights. The mind instinctively turns away from red and the signals would be more easily understood if that small change were made.

He was pleased to see the Author's speed signals. The vertically-arranged type of signal was the one to be preferred. It was the most economical arrangement. The signals could be erected in very confined spaces between tracks and the aspects could be kept low. The illustrations in appendix H showed that very clearly. In order to obtain the fullest benefit from colour light signalling, particularly in the direction of fog penetration, the ideal arrangement was that the beams of light should be on a level with the driver's eye. That ideal was most nearly approached in the vertical arrangements shown in appendix H. Where there was a space between tracks of 10-ft. 6-ins. there was ample room for the signal. It could be fixed in considerably less space than that if the target on the marker light be left off.

The aspects were logical and easily understood. Reading appendix G from right to left they had green for full speed or "clear" and grading down through yellow and green, double yellow, single yellow to red for "stop". Thus by reading the signal from the top downwards, the driver was instructed as to the condition of the line ahead and could regulate the running of his train accordingly.

Although the vertical arrangement of the aspects was to be preferred, they knew that there were places where roads were so close together that there was no room for signal posts. In such places the signals must be supported either on brackets or on gantries. In such cases the lowest light—the marker—must necessarily be higher than when fixed on a plain post. In such cases there was an argument in favour of a horizontal arrangement in order again to keep the lights as nearly as possible on a level with the driver's eye. The vertical signal carries the marker light at 8-ft. above rail level and the first signal light at 12-ft. If mounted on a gantry the corresponding figures must necessarily be increased. There was something to be said for a horizontal displacement of diverging signals, under those conditions, in order to keep the main line signal near to the driver's eye.

The Author deserved the thanks of the Institution for the care and trouble he had taken in preparing his most interesting

paper and he thought that the officers of the L.M.S.R. were to be congratulated on being broad-minded enough to accept and try-out the Author's ideas.

The Author's reply to Mr. Glenn.

Mr. Glenn refers to the arrangement of putting out the marker light—red—when the green aspect is displayed above it. Mr. Bushrod raised that point at the previous discussion at the Institute of Transport and he would therefore read the reply given to that gentleman. (The Author then read from "Mr. Bushrod was a traffic officer" in the seventh paragraph of his reply—page 117—to "home 'off,' distant 'on,'" at the end of the twelfth paragraph.)

With regard to the choice of the splitting distant aspect, it appears that Mr. Glenn, in common with some others, does not appreciate that these aspects are absolutely identical with the arrangement of semaphore aspects with which drivers are familiar. Yellow is the only colour that can logically be used for the indicator lights; that being the standard normal colour of a distant signal in the "on" position. If red were used, the aspect would conflict with junction stop signals where geographically arranged and would undoubtedly lead to confusion.

Mr. R. S. Griffiths would preface his remarks by saying that he had endeavoured to approach the subject from the driver's point of view, and as one who still had an unrepentant admiration for the Signal Engineers of an early generation who were not afraid, with the limited means then available, to put up signals so as to give the least unmistakeable meaning to the driver, even if that meant going to some considerable height, and perhaps unusual shape, to obtain that most desired result.

The modern colour light signals had, in themselves, solved many of the difficulties which then presented themselves, but since the Author stated on page 66 that colour light signals should not be employed other than for multiple-aspect signalling, and since the difference in form from the old semaphore was so apparent, he did not see why he should consider at all the aspects used prior to its introduction. In fact, he would only do so in one, or, at the most, two cases.

In one of these the Author used a single green light for "proceed," as was done with the night indication of many of the semaphore type; he never used a single red as existed to-day.

When, however, the Author wished to adopt a fifth aspect, he referred to the old system as an argument for not using green over yellow, even though the complete aspect would, the Speaker assumed, be green over yellow over red. As with the exception of green at least two lights were always used, why not stick to that and give green over yellow over red, and green over green, particularly as green over green was to-day the least restrictive aspect?

Was the Author quite consistent throughout? On sheet 2 of appendix C he always had his marker light illuminated, even if the top light was green (Fig. 159). He thought, therefore, with green over yellow, should the yellow go out, the Author did not get the full signal "proceed" which required two greens.

The Author argued that the yellow was graded by the lights underneath which, as an argument, gave undue prominence to the yellow. One could as forcibly, and perhaps more so, say that the restrictions are always removed first by the top light.

Thus :—	Red	Yellow	Yellow	Green	Green
	Red.	Red.	Yellow.	Yellow.	Green.

that is, the bottom light followed the previous colour of the top light or that the top light was restricted always by the lower one, further emphasized by a red marker light at the bottom.

When one came to compare speed signalling with manual block signalling they found seven indications suggested for the four now used at a junction. He did not quite understand why, under some circumstances, as much information about the low-speed route was not provided as was suggested for the high-speed route, and, if it should be, then another indication, presumably red over yellow over green over red would be the indication corresponding to 158 for main line.

That gave eight indications; add the "danger" aspect, all red—Figs. 134 and 137—and three possible marker light indications, and they got twelve combinations to be memorized. If by any chance the slow-speed route was closed, and therefore the main line signals could be automatic, the marker light would require two positions, adding a further three aspects—a possible total for a two-route junction of no less than 15 indications.

He inclined to the opinion that, as they do not and could not avoid passing the red, as the Author stated on page 67, little was gained in clarity over the geographical method for the small amount saved, as only one more unit would be employed, the

marker light remaining on the main stem and available as in the manner proposed by the Author.

A driver would thus know, where more than one route existed, the particular route by geographical arrangement, and such other detailed information of such route, by a similar method to that displayed on other portions of the railway where only one route existed.

He thought the adoption of multiple-aspect signalling was hindered, rather than facilitated, by trying to make it fit junction working. Every signal for every route could more nearly be identical by retaining geographical arrangement, and follow the laudable object contained in the first paragraph of the paper.

On page 68, the Author stated in paragraph (e) both fixings C and D would be necessary, but no drawing was shown, and the Speaker did not see from his drawing, appendix H, how that could be done without a special unit which, he presumed, was not the Author's intention. Either he must put the marker light 18-ins. out at least—not 10-ins. as suggested—which would appear to foul an open carriage door or put his units 10-ins. to the left for automatic and 10-ins. to the right for interlocked signals.

One other point :—the question of bracket signals as referred to by the Author on page 86. It could be assumed that the placing of light signal units sufficiently staggered to give geographical form was far less difficult than was the case with the old semaphore. Appendix H would appear to show that very little additional elevation would be necessary to place units of 2-ft. or 2-ft. 6-ins. centres and a similar variation in height. He would think, however, that the number of sites where signals need not, or cannot, be placed in a space between running lines largely exceeds the available locations.

The Author's Reply to Mr. Griffiths.

Mr. Griffiths refers to the multiplicity of aspects. This is hardly fair as we are all familiar with four-aspect signalling in this country ; it is standard practice on several railways. The only additional aspect I have introduced is a fifth aspect Y/G and I venture to say that before a long time has elapsed it will be found a fifth aspect is required and my prophecy will be vindicated.

Taking the case of the number of lights at a diverging junction, many cases exist, under semaphore signalling, where at night you see rows of red lights with possibly various yellow ones beneath. I can call to mind a case where there are 22 such lights

and a driver has to grope for a solitary green to permit him to pass such a cluster. I cannot think that reading a maximum of four vertical lights is going to offer any greater problem. Drivers would quite readily appreciate the difference between high, medium and shunting speed by the relative position of the lights; the value of the colours displayed in either position being readily recognised and obeyed instinctively.

The sequential arrangement of aspects for a five-aspect system as suggested by Mr. Griffiths is certainly at first sight attractive, but, if you recollect, Mr. Pick made a similar suggestion and I went to some pains to explain why you cannot use G/Y for the fifth aspect, the reason will also be found on page 71 of the paper.

The use of Y/G commended itself to me because it is totally different from anything that we have to-day, also that the yellow or cautionary aspect is graded or qualified by a subsidiary light in correct sequential succession; that appears to offer the ideal combination.

Regarding the use of two greens, no useful purpose is served by the second green which therefore becomes an unnecessary expense both in first cost and subsequent upkeep. Throughout the proposed system the principle has been observed that lights only show when serving some definite and useful purpose; at all other times they are extinguished.

Mr. B. F. Wagenrieder said that one of the chief points of interest, from an operating point of view, was the question of overlaps. He had never regarded an overlap as provided against a driver missing a signal—except perhaps in fog—but rather as a margin for error in stopping at a signal. Signalling had certainly greatly improved since 1878 when the quarter-of-a-mile overlap first appeared in the rule book of some railways, but he thought that the records of the over-running of stop signals showed that some margin was advisable in clear weather. He would like to ask the Author if he had reviewed such records before coming to the decision that a minimum of 200 yards was sufficient.

The question of unfitted trains was dismissed in one paragraph on page 76. Such trains however constitute about one-third of the total train mileage, and he thought that the proposal to make a junction "free" with the limited overlap B-S, subject to a minimum of 200 yards, required very careful consideration.

At an ordinary double line junction a side collision between two opposite-direction trains can, to all intents and purposes, be a head-on collision.

Block telegraph regulation 5 was referred to as an anachronism. It was, he believed, introduced at certain places at the same time as the quarter-of-a-mile overlap, by the special authority of the Superintendent. Whatever the point of view about that form of block acceptance, it did prove that at the box where the train was stopped, or severely checked and cautioned, the driver was on the alert and had his train under control. It also warned him not to expect the next box home signal to be lowered for his train to run up to the starting signal.

In regard to the tightening up of the definition of "fog" and the application of fog-working when visibility is less than half-a-mile, whilst this might be practicable in the vicinity of signal-boxes in most cases, there were many instances where a signalman could only see a few hundred yards on one side owing to bridges, etc.; also smoke might blow across the line, reducing visibility considerably. A factor of greater certainty, and regularity of traffic working, would be gained by defining fog as visibility of less than say 300 yards and placing some reliance on the enginmen's knowledge of locality and gradient so as to avoid providing long emergency braking distances on falling gradients.

There was no doubt that the paper was one of the most important that had been given for a long time, but its preparation and publication deserved something more than thought on the part of those concerned in signalling. He considered that the Traffic Department stood to gain by the adoption of some of its principles.

The Author's reply to Mr. Wagenrieder.

I am very glad to hear a Traffic Officer refer to the question of overlaps, as it is certainly time that matter was tackled.

I have never been able definitely to ascertain if the quarter-of-a-mile overlap was intended to safeguard a driver who ran by signals at "danger" or merely to cover an error of judgment when stopping; if the latter, then it appears to be unnecessarily restrictive, as a review of records over a number of years shows that a distance of 200 yards would be ample.

Referring to rule 5, Mr. Wagenrieder states that it ensures drivers being on the alert. I wonder, as cases are on record

of the rule being properly carried out, but afterwards the driver promptly runs by the home signal of the box ahead.

If block working is materially eased, as suggested in the paper, during clear weather, the definition of "fog" must be tightened up, and I consider visibility of half-a-mile must be our new standard to safeguard operation during foggy weather. Under such conditions you revert to the working you have to-day, *i.e.*, at an occupied junction, an approaching train is kept back at the box in the rear, but during clear weather, which, after all, is the condition during the greater part of the year, you gain the benefit which the greater clarity of the colour light signal should confer.

Mr. Wagenrieder asks whether colour light signalling can be relied on in foggy weather. I think I am right in saying that on all those railways where colour light signals are installed on the multiple-aspect principle, fogmen are not provided. During a recent winter in Manchester, when a dense fog lasting nearly 120 hours occurred, traffic worked exceedingly well during the whole period although no fogmen were employed.

Mr. T. S. Lascelles said that he had read the paper very carefully but it was rather long and raised so many contentious points that it was impossible to do justice to it in the time at their disposal. He had greatly enjoyed reading it, as signal aspects were a subject he had long been interested in. The Author was doubtless quite right in pressing for some standardisation or agreement in that important matter and he had pointed out very clearly what would happen if that were not soon taken in hand. Signal aspects were, however, still far from uniform in America, and in spite of the action of the Signal Section of the American Railway Association, new proposals were constantly appearing in the technical press. Of course signal aspects were a subject on which everybody liked his own fancies best and that made many difficulties.

The Author had spoken of the light-signal as being certain to supersede the semaphore and in that he voiced an opinion very popular just now. At the risk of being thought old-fashioned by the meeting, the speaker would ask whether they were right in throwing the semaphore aside in the way they were doing. An American signal engineer had said that they seemed to be going "light signal mad." That light signals possessed certain—even great—advantages was true. But it could not

be denied that in bright daylight they were not always satisfactory. Lights were not natural things to look at in the day-time. After all, the ideal signal was one which was equally plain to the man who had to read it, all the way along after he sighted it. Light signals, as at present made, were not. They got a tremendous beam for an instant very often, and then nothing for the rest of the way. That meant that a signal in the distance was more immediately arrestive than one close to, which was a wrong principle and had already led to drivers overlooking a signal at which they were standing and reading one farther on. As an example, take a terminus like Charing Cross. At the motor-man's cab they could barely see a glimmer out of a signal in the day-time but got a tremendous glare when talking to the ticket-collector. Another serious objection to light signals was that other persons about a station could not tell what the condition of the signals was, which it was often useful for them to be able to do. Sometimes, too, at inquiries, the testimony of other persons as to the condition of the signals was very valuable in establishing the facts, but if only someone in line with a signal could see its indications that advantage was gone. This question was always discussed as if the only alternative to a light signal was the semaphore with the present miserable oil lighting. But that was not so. Why could not they put a colour light lamp behind the spectacle and give a driver all the best of both? If he were offered that the speaker believed he would prefer it to any other arrangement.

If, however, they were to have light signals, then the speaker thought that the best kind invented so far was the position colour light of the Baltimore and Ohio Railway. Had the Author chosen that he would have avoided many difficulties, notably the problem of differentiating red from yellow; to meet which, among other things, he had adopted red marker lights. The speaker could not yet believe that marker lights were really necessary and would remind the Author that their use in America was not so universal as he appeared to think. Still the suppression of them at "proceed" did remove the most serious objection to their use.

With regard to the terms "aspect" and "indication", some confusion had crept in which needed clearing away. The old term "three-position signalling" meant signalling in which three positions of a semaphore were all that were recognized, and

they were 0, 45-deg, 90-deg. to the horizontal in one quadrant. The adoption of lights only made the term "position" no longer correct and "aspect" was introduced. Perhaps "colour" would have been better. They thus had three "aspects" *viz.*, red, yellow and green. The putting of two yellows on a post did not make a fourth aspect; it enabled us to get a fourth indication merely. The system was still a three-aspect, *i.e.*, a three-colour system.

Mr. Lascelles thought that if a fifth indication were sometimes required, as the Author contended, then the logical thing to do was to have three yellow lights, giving triple yellow, double yellow, single yellow, red. In that way all the warning indications would be all yellow, as was the intention when the Committee recommended the double yellow indication. No difficulty then arose if a light failed.

With regard to the overlap, the speaker thought that the Author was mistaken as to its origin. The fundamental idea of the block system was to preserve an interval of space between trains. The overlap did that; for without it one train could come up to another with only the thickness of a signal post between them. The minimum interval was aimed at to give some margin for errors of judgment, which the thickness of a post would not afford.

He was an advocate of route signalling but the speaker could certainly say he had never talked about "27 indications." Of course that expression was all nonsense and showed that whoever used it had not really studied speed signal systems at all*. His point of view had always been this:—What is the natural thing for a person to ask when driving a vehicle on a fixed track, whose path is decided by another person? Surely it is "Where is that other person sending me?"

The Speaker was still convinced that the natural thing to tell the driver was where he was being directed and then leave the driving to him. He felt he would prefer that, if he were in charge of an engine, and for that reason was a route-signalling man. No doubt for a plain crossover-junction the vertically arranged

* The origin of the error as to 26 indications arose out of the diagram of the standard signals on the Pennsylvania Railroad giving 26 aspects. As Mr. A. H. Rudd pointed out in a letter that may be found on page 130 of the *Railway Gazette* of February 2nd, 1917, some were duplicates; the number of aspects actually was 14. *Editor, Proceedings.*

speed signal was quite sufficient. But for a true junction, the speaker still believed there was no more sensible signal than the British bracket type. To point to America served no purpose, for the bracket junction signal had never been seen there, or so little as to be unknown now.

The Author had spoken of shunt signals and the Speaker quite agreed with him that lights were far from satisfactory, and that some kind of form or position signal was much better. The use of it removed the vexed question of the colours to be used in shunt signals. So, too, the Speaker cordially supported the Author in his plea for something to be done before more money was wasted on creating further divergencies in practice. They ought to go very warily in those things. Money had been wasted in hasty adoptions on what were often little more than academic fashions. Take the yellow distant signal, as an example. On the three systems forming the Southern Railway the distant signals had long been fitted with distinguishing fishtail lanterns. The drivers were very well satisfied with these. They could tell a distant signal when "on" or "off". Then came the yellow signal craze. All those lanterns were changed, glasses were changed, new enamelled arms provided, etc., all at great cost. The trains ran no better and no safer. The drivers lost an advantage they had before and now could not tell a distant signal when "off". But scarcely had all this money been spent than colour light signalling was put in, and was now being extended to Brighton. So that a vast expense had been incurred and no advantage whatever reaped from it, either for the company or the public. It was essential that they should think more about the changes the future would bring before embarking on expensive steps, and the Author's warning was a most timely one.

In conclusion the Speaker emphasised that the problem facing the railways to-day was how to get more people to go by train; and even signalling arrangements needed considering from that point of view.

The Author's reply to Mr. Lascelles.

Mr. Lascelles raises the point as to whether we are right in adopting light signals at all. Anyone who has spent hours, as I have, on the track, trying to provide semaphore signals giving a satisfactory sight where local conditions are difficult, will appreciate the tremendous advantage conferred by light signals.

It may almost be said that the worse the background is under our old standards the better it is for visibility of light signals; in fact one can almost settle the latter without going on the ground.

I agree that on a very bright day, with a good sky background, a semaphore arm would win in a matter of ultimate visibility, but, after all, a good colour light signal can be seen for 1,000 yards under similar conditions, and this is amply sufficient, especially where multiple-aspect working is employed.

With regard to the close-up view of light signals, I agree with the Speaker that they leave something to be desired and efforts should be, and are being, made successfully to considerably improve that. Further, the question of fitting a backlight is being tackled and colour light signals with such a fitting are now available. No doubt it is not as clear an indication as the rear view of a semaphore arm, but this question of availability of warning to ground staff is entirely a subsidiary one and should not be allowed to affect the main consideration of providing the best possible signal for a driver.

I agree that the colour position-light, as used on the Baltimore and Ohio, is a very interesting one. Its application is shown in appendix A, but I do not think it would appeal to English ideas.

As regards the marker light, I know its use is by no means universal in America and I do not suggest its use here because it is used in that country, but solely because my experience of it over there convinced me that it afforded a satisfactory solution of many of our problems.

The speaker refers to certain unnecessary changes which have been made on one of our railways. I will leave the representative of that railway, present here to-night, to reply.

Mr. G. H. Crook thought it might possibly be of interest to members to know that his company—the Great Western—had installed more searchlight type of light signals than of any other form. It was certainly a magnificent signal optically, and if he had any regret it was because of the somewhat more complicated circuits that were involved than those required for multiple-lens signals. However, the signals were provided primarily for the drivers' information, and if they had any slight technical difficulties in that respect it was entirely the Signal Engineer's domestic business.

He thought that possibly the Author had been somewhat

circumscribed in these signalling problems with what had gone before, and as Mr. Rudd, the eminent American signal engineer, had been mentioned once or twice in connection with the paper, he might take the opportunity of saying that he understood that when Mr. Rudd and his collaborator, Mr. Rhea, received their mandate of inquiry, sometime prior to 1905, they were asked to report what the Pennsylvania Railway ought to do independent of any pre-existing signalling practice. The speaker thought that to be a broader and better starting-off point than that adopted in the paper.

For instance, it seemed to the Speaker that the Author had gone to great pains to circumvent that unfortunate aspect in route signalling, red over yellow, arising since distants had been converted to yellow lights. The lower yellow light in connection with a stop signal was technically wrong and contradictory. The red light said "stop" and the yellow light said "go". The change was reasonable in the case of isolated distant signals, but in the case of home and distant signals, considerable money was being spent for no practical gain. He considered that history would record that change as representing the unbalanced psychological attitude immediately following the War, and he regretted that the Author had not been able to take up a stronger attitude, and pitch overboard completely that very unsatisfactory aspect.

Years had passed and the systems tended to become more and more complicated, and the Author, in his splendid paper, endeavoured to set out some of their difficulties and make some recommendations which might be discussed, but it was impossible in a short time to go into much detail.

Some of the proposed indications showed no less than four lights, but the speaker thought that two or, at most, three were all that should be necessary. It seemed to him that they needed to consider three important fundamentals which he would submit as :—

Red for "Stop."

Yellow—unless qualified by combination of a superior colour—"Caution—Be prepared to stop at next signal."

Green—unless qualified by combination of a more restrictive colour, *e.g.*, yellow—"Proceed."

If they worked on these simple fundamentals he could not

entirely agree with the proposal for low-speed or calling-on signals, under which, apparently yellow and green were to differentiate " track occupied " and " track clear," and were not dependent upon the signal ahead. The speaker did not think that either yellow or green could very consistently be used for these low-speed movements, and the circumstances seemed to suggest a quite distinctive non-colour, *e.g.*, white, position light, signal as the best and only consistent solution.

He rather regretted to see the Author found it necessary to retain the double yellow aspect. He also noted the proposed combination of closely spaced lights, in some cases three lights at 2-ft. centres, plus a marker at 4-ft. He was hoping that they would have had something bolder and on more simple lines, and thought that they ought to be able to design a signalling system with not more than three lights showing.

In appendix C, sheet 2, aspects 146, 157, 158, 150, 162, there were four lights showing, and he considered it would take a long time for the drivers to properly appreciate the true significance of those fine variations. The colour combinations were too complicated, especially considering the close spacing of the top lights. In this connection it might be interesting to say that when installing colour light signalling on the Great Western line a minimum spacing of 5-ft. for vertical or horizontal was laid down.

That was nothing new, and he thought that liberal spacing of lights was very desirable, particularly for high-speed traffic.

In showing those various diagrams he thought it would have been much clearer if the black dots had been omitted. From a Traffic and Locomotive Department point of view the black dots represent no light and were meaningless. In the aspects named he suggested that only the lights actually shown need be indicated on the diagrams.

With regard to marker lights, he was interested to see the way they had been staggered. He supposed the Author had implicitly followed American practice, *i.e.*, signals on the right, and running on the right. Where there was left-hand running the Speaker's experience had been to reverse the arrangement, and the marker light was on the right of the post. He would be glad to know whether there was any particular reason for placing the marker light on the left. So far as extinguishing marker lights was concerned, he had not, in his experience, met with any

necessity for extinguishing them. The marker gave the driver a complete picture of the signal, whether at " stop," " caution," " proceed " or otherwise.

Block rule 5 had been referred to. He would instance an actual case as an absurdity to which the rule could be taken. On Sundays, several boxes were switched out where section-clear-junction-blocked was administered. There the driver passed a number of distant and home signals in the " clear " position ; eventually coming to the junction, which was at one time blocked, and which had perhaps been cleared half-an-hour before the arrival of the train !

He appreciated the Author's intensive study and his fine progressive action ; at the same time he was definitely of opinion that a straight-out scheme of speed signalling, or at all events a scheme taking speed as the principal basis, was the better proposition. The move he had made with regard to simplifying junction signals was commendable. The speaker, however, regretted that it was still considered necessary to provide distant aspects leading up to the junction signals. It was, in his opinion, almost incorrect, even under a route signalling scheme, to give routing information at a point where there could be no divergence. Splitting distants, at perhaps a mile from the junction, gave directional route information. Then perhaps the driver encountered an outer home signal which was uni-directional, subsequently reaching home signals which were directional. In any case the splitting distants only gave route information if in the " clear " position. It seemed to the Speaker that the only thing the driver could do, at the distant signal, was to suitably reduce speed or alternatively carry on at full speed, and a speed indicating signal was therefore the only logical indication that could, or should, be given.

He would finally express his appreciation to the Author and hoped his own comment was to be regarded as well meant and constructive.

The Author's reply to Mr. Crook.

I am not at all disappointed with Mr. Crook's comments ; we are all aware of his leaning towards speed signalling.

He refers to the Pennsylvania Railroad designing their signalling independent of any pre-existing practice. I have already been taken to task for breaking away from tradition and if I had dared to design a system fulfilling such a condition

I cannot imagine what would have happened to me. My line of approach has been just the opposite, and in view of the almost universal standardisation of signalling in this country, I submit that is the only reasonable thing to do, namely, to have every regard for what exists to-day and interweave what is new into the pattern so as to avoid all overlapping and confusion between the old and new systems, and I must leave it to the future to say if I have succeeded.

With regard to the unfortunate aspect R/Y, I think Mr. Crook will find I have pitched it overboard so far as its present application is concerned.

I have no sympathy with liberal spacing, the essential feature in arranging colour light signals is to bring them as near as possible to the driver's line of vision, so as to gain the maximum benefit in time of fog. Liberal spacing is antagonistic to that, and as experience shows that at 2-ft. they are perfectly distinct at a reasonable distance this minimum spacing was adopted.

It is for this reason the marker light is fixed on the left where staggered, thus allowing the mast and main light to be brought as near to the track as minimum clearance limits allow.

With regard to splitting distant aspects, a very good way to answer the speaker's question is to ask him another and that is " What would he do if his Traffic Officers insist that the colour light equivalent of directing distants be provided ? " Would he say it could not be done - an answer detrimental to the extended use of colour light signalling ? I think not and I submit I have shown the only logical solution.

Mr. H. M. Proud would not like the occasion to pass without thanking the Author for his outstanding paper. The more deeply it was studied, the more one realised the very close investigation and the logical manner in which the whole signalling system outlined had been developed. He had examined the paper to find, if he could, a snag therein. At first glance certain novel arrangements appeared to have that character, but closer reading of the paper showed that the difficulty had been anticipated and the solution well thought out. He felt that the Institution owed a deep debt of gratitude to the Author for the paper which he had so ably prepared.

He was very much interested in the fact that the system was a development of that prepared by the Three-Position Signalling Committte, held under the Author's chairmanship,

and in the way in which that gentleman had contrived to carry on from that point and to devise a system which enabled the new system to be gradually introduced and to be mixed up, during its introduction, with the existing signalling. It would appear that the paper visualised a future time when there would be complete track circuiting and, possibly, colour light signalling throughout the railways.

He did not feel that he could criticise the system put forward, as it was based on such logical arguments, but it had occurred to him that the question of cost would have to be kept in view. No doubt the Author had had that in mind, and undoubtedly, if the system was introduced, they would all be working hard to find ways and means of carrying out the installations more cheaply.

With regard to the isolated distant signals referred to on page 91, he had wondered how it would be arranged to hold off the detonator from the line by means of the current which passed through the lamp, if the lamp were approach lighted. It would appear that when the lamp was out, the detonator would be put on to the rail and when the lamp was lit up, would not some mechanism have to be devised to take the detonator off again? Under those conditions, was a machine to be provided to take the detonator off?

On page 79 reference was made to fog switches. While it seemed rather a pity that one should have to leave to the discretion of the signalman as to the times when the trains were to be kept farther back, he could not see a better way of meeting the situation, unless one provided a very complex method of measuring the density of the fog.

Again he thanked the Author for his paper, and felt that, in years to come, it would be treasured more and more.

The Author's reply to Mr. Proud.

Mr. Proud has briefly referred to the question of cost and I hope it will be appreciated that the system, as set out, is not necessarily an expensive system. In fact the introduction of speed signalling, assuming the use of the fourth and fifth aspect and also the marker light, effects a considerable economy. In matters such as this it is entirely a question of degree and the return obtained for the money spent, and I can assure Mr. Proud that we want to see a return of 20/- for every pound spent. The only major addition, compared with common practice to-day,

is the addition of the marker light and on the total cost of the installation these lights form quite a small percentage, bearing in mind the saving which can be achieved in regard to light indication in the signal-box.

With regard to detonator placers as proposed at isolated distant signals, there is no insuperable difficulty in holding the detonator off the rail, even though the signal is approach lighted. That would be effected by parallel circuits controlled by the lamp or relative track. Instances of this arrangement are already in practical use and by means of the same the only time that the detonator falls on to the rail is in the event of a lamp failing to light or remain alight, due to a burnt-out filament, and it is not necessary therefore to provide a machine to take the detonator off the rail.

With reference to the proposed fog switches a certain amount of responsibility must always rest with the signalman, and for that reason it is felt that such a switch, available to the men on the spot, would probably be a better measure of protection than any device such as a photo-electric cell which has from time to time been suggested for purposes such as that.

I should like to thank Mr. Proud for his comments which are most encouraging.

Mr. W. Challis said that during the past two years, where colour light signalling was in use on the Southern Railway the services of fogmen had not been necessary and they had been withdrawn.

The Author had unkindly thrown on him the onus of replying to the point made by Mr. Lascelles about the change which had taken place with regard to the signals on the Southern Railway. He could only say that it was the case of an old custom changed to a new. That was done, he believed, by all the railway companies and, further, it was supported by the Ministry of Transport; that is, the distant signals should be changed from red to yellow. He could assure Mr. Lascelles that the changing of the signals, which he considered unnecessary, did show an economy.

The marker light, so well advocated by the Author might, or might not be necessary. During years of experience he had not found the marker light necessary. The close-up view of colour light signals was not good, neither, he might say, was that of the semaphores. The Southern Railway was trying to improve that by providing side lights to every signal and to each aspect, as

they felt that the driver should be given every assistance possible.

The Author considered the indication of lamps was unnecessary if there were marker lights. He could not, after 20 years' experience with light signals, agree with him there. Going back only 15 years, the aspects were not indicated, and if the train did not arrive, and the signal remained at red, the driver of the train was only doing his duty by staying there. The signalman would not know the signal had failed and much delay would result. It was therefore found necessary to provide indications of the signal to the signalman. After all, if a driver did run past a signal, he was only human. The signalman having the indications of aspects in his signal-box was a great help and he could always state what aspect was showing.

The Author also said that double yellow might lead up to a less restrictive indication. He could not quite see what he meant there. He felt that a driver passing a double yellow, the signal ahead should only show one yellow.

His difficulty with regard to approach lighting of signals was that if they could afford to have the signals out there it could not possibly be a very dense service of trains and the question came to his mind why colour light signals were necessary at all in such areas.

Although his company used colour light shunting signals, he thought from the experience they had had and the difficulty in seeing them under certain conditions that the Author was right in having the illuminated banner signal. With regard to the marker light being used for a calling-on signal he did not quite see how that could be arranged. Then, in regard to the marker light on automatic or semi-automatic signals, as on occasions signal-boxes might be switched out and the signal become an automatic signal, he was not quite clear how the Author suggested that they should get over that difficulty. Up to the present time the Southern had not found it necessary to provide a calling-on signal in a multiple-aspect area.

He felt that they ought to tell the driver where he was going and to help him in every possible way they could and provide geographical signals at diverging junctions. With regard to terminal working and the green aspect for clear to buffer stops. A driver knew when he was going to a buffer stop. From his own experience he did not think that the Author's suggestion was warranted.

The Author's reply to Mr. Challis.

I am glad to have Mr. Challis's testimony on record that during the past two years in the colour light signalling area on the Southern Railway the services of fogmen have not been found necessary and that they have been withdrawn.

The Speaker states that during his years of experience he has not found the marker light necessary. One can readily believe this, as it is less than ten years since colour light signals were first used on steam roads and quite naturally, with only a few isolated installations, no driver would be likely to mistake the meaning of such signals, but if one looks ahead in view of recent developments and visualises the possibility of the adoption of colour light signals, not only to particular areas, but also in isolated cases up and down the line, I think it will be appreciated that something will have to be done to enable the driver to understand the meaning conveyed by two totally different systems of signalling through the common process of a coloured beam projected from an electric lamp, and it is possible that after the speaker has had another ten years' experience he may be more ready to agree with the proposed use of the marker lamp and I would go further and say that when such experience with the marker light has been gained it is possible that his opinion as to the necessity for the indication of lamps may be modified.

Mr. Challis suggests that a double yellow should always lead up to a signal showing one yellow, but does not indicate why he holds this opinion. The indication conveyed by the double yellow is that the next signal may be passed but at restricted speed and as such restricted speed may be due either to a restriction brought about by the presence of a train ahead or by a permanent speed restriction, as for instance when passing a train through a double crossover from one line to another, it appears to be immaterial what the aspect is ahead.

The proposals relative to approach lighting of signals have probably been misunderstood. If the density of traffic over a given section of line is such as to necessitate colour light signals arranged on a close headway basis, no one would for one moment suggest that such signals should be approach lighted; on the other hand should one desire to use colour light signals as automatics for the purpose of splitting up a block section on a line which may not be so frequently used, then there is every good

reason why an attempt should be made to approach light such signals, especially if battery operation is under contemplation.

I am glad to note the Speaker's preference for illuminated banner signals, in view of his experience in colour light signalling work generally.

In the use of the marker light for a calling-on signal there is no difficulty; it simply means that the red marker is regarded as the normal aspect of the calling-on unit, such red going out when the small yellow comes up, authorising a movement past the signal on to occupied territory. There is also no difficulty in dealing with the marker light in those cases where signals are sometimes automatic and sometimes controlled, the marker being arranged as a double unit, one red lens being vertically under the main signal and the other displaced 10-ins. to the left. One of these is illuminated according to whether a signal is acting automatically or semi-automatically, being selected by the operation of the closing switch.

The **President** was sure that the Author must feel very satisfied with the discussion that evening. Personally he did not know which he admired the most the wonderfully fine paper he had prepared for them, or the admirable way in which he had replied so adequately to each speaker in turn, practically on the spur of the moment.

He would like them to support him in voting the Author a very hearty and sincere vote of thanks for one of the best papers the Institution had ever had. It had given them much food for thought and would continue to do so for a long time to come.

Before he concluded he would like to say with regard to Mr. Lascelles' remarks and the bold stand that gentleman made for the old semaphore type of signal as against the colour light, that he recalled the time when the section from Marylebone to Neasden was being resignalled in connection with the Exhibition in 1923. That section was originally intended for motor-worked semaphore automatic signals, but several of them, owing to bad sight when approaching the Marylebone tunnels, were found to be so difficult to see that colour light signals were eventually decided upon and had given the greatest possible satisfaction since. Day colour light signals were here and were here to stay.

Major Morkill said it gave him great pleasure to second the President's proposal. The paper was appreciated by all the

members and it was one which would live with them for some considerable time.

The **Author** thanked the President and members present for the kind way they had received the paper and for the manner in which they had put forward their criticisms. It had given him very great pleasure to write what he hoped had proved of interest.

Mr. A. Moss (in a written communication) said that the question of overlaps was by no means a simple problem and he was somewhat in doubt as to the Author's intentions. On page 76 it was stated " that where mechanical control is absent, overlaps are essential and should always be equal to the emergency braking distance," but on page 77, in the penultimate paragraph, similar overlaps were given as equalling full braking distance, the latter also applying to what was known as the full block overlap system. Again, when applying overlaps to protective colour light signals, 200 yards were suggested as a minimum. Why have a minimum ? If the B-S formula was effective at 300 yards should it not be similarly effective at 100 yards ? His impression was that to have a fixed minimum was perpetuating, in a lesser degree, the anomaly associated with the present 440 yards. Would not overlaps based upon the E.B.D. give the maximum security in all cases ? The calculating of overlaps from the sighting point might be both mathematically and theoretically correct. The difficulty appeared to be able to work the driver in with the same degree of mathematical accuracy.

The proposal as to permissive marker lights seemed to fix one's attention upon the question of a given signal indication being capable of two interpretations, *i.e.*, a calling-on signal with section ahead occupied or operation of the one-minute rule. Was it quite desirable to legalise the passing of a signal under the one-minute-rule by means of a signal indication in preference to an instruction forming part of the rules under which the particular section was being worked ?

Now that routing was incorporated in the proposed speed signalling indication there could be very few legitimate objections against the proposal. To the driver, having to learn a new set of indications, one form should present no more difficulty to him than any other. No doubt the Author had experimented with three light junction signals showing G/R/R/ and he would like to ask whether it was possible for a driver to clearly sight the green at, say, 800 yards or whether there was a tendency for the

two reds to obliterate the green. On diagram 4, appendix F, the distant routing shown on the middle example should, he thought, be similar to the first example, in order to carry out the proposal of right-hand lamp lighting for left-hand route.

He was particularly interested in the problem of terminal working and the suggested use of a three-vertical-light speed signal seemed to overcome most of the difficulties. One point, however, appeared to arise and that was that if the first train fully occupies the first berth the R/Y/R/ indication would be received by an engine backing on to the train ; if, however, the first train was standing with its rear wheels just on the second berth side of the insulating joint the backing engine would then receive a calling-on indication. He was afraid that under those conditions the driver could hardly be expected to appreciate the necessity for differentiation between the indications given to him. The only solution for a condition of that sort was to fix a signal at the end of the first berth and if that were provided it would be possible to give a correct indication at all times and under all conditions.

He would like to join in the congratulations to the Author. The paper was one which called for a very close study and, to the writer personally, the time spent in assimilating the various proposals and trying out their applications for himself had been well worth the endeavour.

Mr. H. E. Cox (in a written communication) said he considered that the Author had given them a most interesting and instructive paper and one which provided food for considerable study and thought.

It might be of interest to refer to what had been done in India and why. As long ago as 1920, the Great Indian Peninsula Railway attempted to get permission to introduce three-position semaphore signalling—there was at that time no question of using light signals into India. The proposals met with a chilly reception from the then Government Inspector of Railways, who however passed them on to the Railway Board, who in turn sent them to the Indian Railway Conference Association for their views. The consideration of the proposals took about two years and, even although they were approved by the I.R.C.A., they were turned down by the Railway Board of that time on the grounds that the conditions obtaining in India were not suitable for the general introduction of a new system of signalling, which

involved the adoption of a new colour and a special set of block working rules, and that there were very great objections to its introduction. Fortunately, all those responsible for, or in any way concerned with, this adverse decision had retired from India by the time the new General Rules were under consideration. These were eventually published in 1929, and not only included a section dealing with automatic signals, but allowed the use of three-position semaphores and two- and three-indication colour light signals.

In consequence of the adverse decision previously mentioned, the G.I.P. Railway decided to use two-position lower quadrant semaphores, each automatic to be of the home and distant type, and estimates were prepared accordingly for the proposed Bombay Harbour Branch installation.

In view of the success of light signals in the United States and England, it was decided to try out some on the G.I.P. Railway, but it was found that the sunlight of India was much more trying to the daylight indication than was the sunlight of Europe, and that the range of the signal was too much reduced for actual service requirements. Eventually, early in 1924, a third trial was made and was a complete success. The signal was inspected by Heads of Departments and the Government Inspector of Railways and the proposal to use colour light signals on the Harbour Branch installation instead of semaphores was duly approved and later sanctioned by the Railway Board.

The Harbour Branch installation of 9 miles of two-track road and the later and similar Masjid-Byculla installation of 2 miles on the four-track main line were in service and under construction respectively by the time the 1929 General Rules sanctioning three-position or three-indication signalling were published. Therefore, except in a few special cases, each automatic and semi-automatic light signal was of the home and distant type with two two-indication light units. In later installations on other railways in India, three-indication light signals had been used and the G.I.P. would adopt them for future work.

The practice in India was only to have marker lights on automatic signals and these were small purple lights placed below and generally out of line with the signal lights. On the G.I.P. Railway, "A" lamps were also used in those cases where

semi-automatic signals might be temporarily working as automatic signals.

Mr. Cox was a member of the Signal Engineers' Committee of the I.R.C.A. who, in 1924, made the first draft for the new rules for the operation of automatic block signals now embodied in the new General Rules of 1929. Although these draft rules subsequently passed through a number of parties before final adoption, the revisions made were merely those of detail and arrangement. Mr. Cox had proposed the usual red marker, but the rest of the Committee were against him and wanted to get away from another red light. They thought that the marker should be a quite distinctive colour. Eventually, purple was chosen in spite of its low transmission value. He felt bound to say that, in actual practice on the G.I.P. Railway, the purple marker lights had planned out very well. So long as focus lamps were used, a reasonably good range was obtained in bright sunlight, and the fact that the marker had a much shorter range than the signal lights tended, he thought, to make the driver slow up when the signal was red over red and that was an advantage. Further as the marker light was only of significance when the signal aspect was " stop ", the wiring was so arranged that it was only illuminated when that aspect was displayed and this resulted in economies in bulbs and power consumption.

He did not like the Author's proposal of using marker lights on all multiple-aspect signals. Mr. Cox thought it was necessary, particularly in India, to make a very clear distinction between a stop-and-proceed signal and a stop-and-stay signal, so that there was no chance of confusion in a driver's mind.

The practice, which he gathered was growing in England, of merely substituting colour light signals for semaphores and retaining the same aspects and system of working seemed unfortunate, and he quite appreciated the confusion which must ultimately result. He would strongly oppose anything of that kind being done on the G.I.P. Railway.

There were two overlaps recognised in the Indian General Rules, one was the quarter-of-a-mile block overlap, as used in England, and the other was an over-run overlap of 600-ft. He agreed with the Author that if a train was protected at least by a cautionary and a "stop" signal, braking distance apart, no over-run overlap was necessary. Mr. Cox thought, however, that he would not be likely to get any operating officer in India

or Government Inspector of Railways to agree to dispensing altogether with the over-run overlap and reducing the possible distance between two trains to about the thickness of a signal post. They had to think of the vagaries of the Indian driver or motorman.

On the Harbour Branch installation, there was at one time the possibility of train stops being added later, and therefore all the overlaps were calculated to suit the actual requirements of each location, using the same methods as the London Underground Co. Consequently, they varied from about 400-ft. to about 700-ft. Most of the overlaps on this installation were not separate track circuits; this arrangement having been adopted to decrease the cost of the installation and reduce the number of track circuits and impedance bond layouts required. When traffic had become dense enough, it was the intention to make all overlaps separate track circuits.

On the later Masjid-Byculla installation on the main line, the overlaps were a uniform length of 600-ft., merely as an over-run protection and were all separate track circuits. It was proposed to continue this arrangement in future work. He quite agreed with the Author on the desirability of overlaps being separate track circuits.

Mr. Cox did not agree with the recommendation not to use colour light signals as subsidiary signals and dwarfs. The G.I.P. Railway had done so, following American practice, in all their work and there had been no operating difficulty. In fact, he would do exactly the same thing in future work. Globe type dwarf and shunt signals had been installed on one Indian Railway, but he had a poor opinion of them. They had such a short range in Indian sunlight and there was too little difference between the red and the yellow. The same difficulties, short range and poor visibility, applied also to banner signals. Taken on the whole, therefore, he considered a small size colour light signal the best proposition.

The Author very rightly stressed the importance of keeping the height of light signals down to the level of the driver's eyes. Mr. Cox knew of one or two Indian Railways, where they had been fixed too high, possibly because the particular railways had always favoured very high semaphore signals. In one case, since the installation was brought into service, the light units had been lowered. On the G.I.P. Railway, except in the few cases where

they had had to use gantries, a single unit signal and the lower unit of a two-unit was always fixed 10-ft. above rail level; that height being approximately level with the motormen's eyes. The upper unit was always fixed 5-ft. above the lower unit and the marker light 2-ft. 6-ins. below the lower unit.

Those who had looked at the 1929 Indian General Rules would be aware that an isolated warner, *i.e.*, distant signal might now be provided with a yellow arm and light as an alternative to the well-known Indian practice of showing a fixed green light above a red arm and light. The G.I.P. Railway had just prepared an estimate for changing over the isolated warner signals in the suburban area to yellow arms and lights, as the saving due to the removal of the fixed green lights provided an ample financial justification for the change. There was no intention, however, of changing over those warners under home or starting signals, even although such a change was permitted under the Rules. The red over yellow aspect was not only illogical and contradictory in itself, but was open to grave objection due to the different systems of block working used in India. Under "B" class working, line-clear could be given when the line was clear up to the home signal, which meant that a train standing, or shunting being carried on, inside the home signal was protected by the quarter-of-a-mile block overlap provided between the outer and home signals. Under "A" class working, line-clear could only be given when the line was clear up to the starting signal. That meant that the requisite conditions were very similar to those in force in England. It would therefore be seen that if a red over yellow aspect was provided at a "B" class station and the red light failed, a driver might think he was approaching an "A" class station, with the result that, if the line beyond the home signal was obstructed, there would be great risk of a collision occurring.

COLOUR LIGHT SIGNALLING IN RELATION TO MANUAL BLOCK AND MULTIPLE ASPECT SIGNALS (BOUND)

APPENDIX A.
SHEET 1.

AMERICAN SIGNAL ASPECTS & SYMBOLS

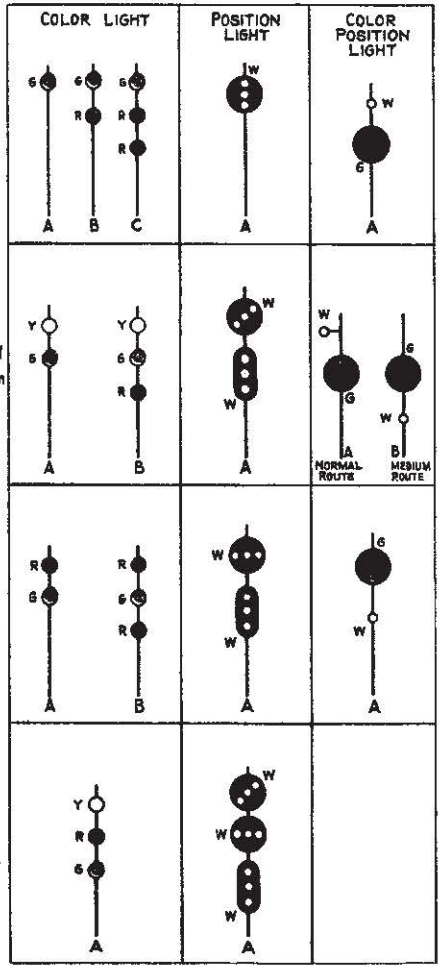


Figure 4 A.R.A.
Indication - Proceed
Name - Clear

Figure 5 A.R.A.
Indication - Approach next signal at not exceeding medium speed
Name - Approach-Medium

Figure 6 A.R.A.
Indication - Proceed at not exceeding medium speed
Name - Clear - Medium

Figure 7 A.R.A.
Indication - Approach next signal at not exceeding slow speed.
Name - Approach - Slow.

APPENDIX A.
SHEET 2.

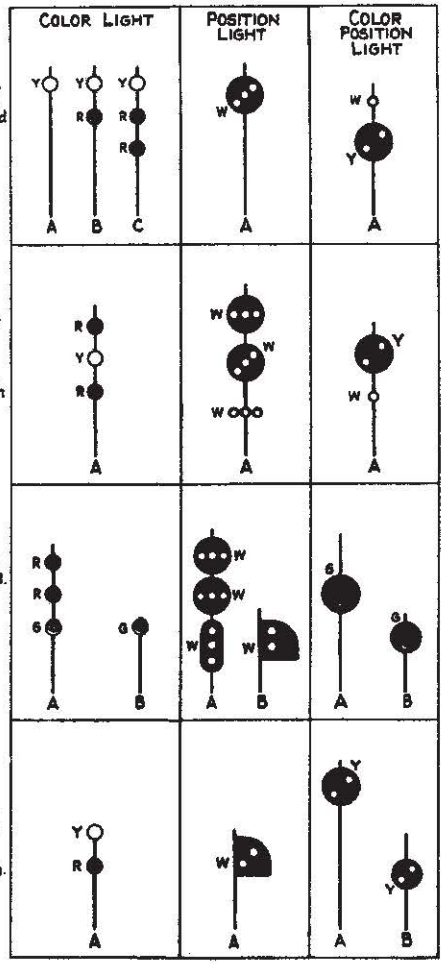


Figure 8 A.R.A.
Indication - Prepare to stop at next Signal. Train exceeding Medium Speed must at once reduce to that Speed.
Name - Approach.

Figure 9 A.R.A.
Indication - Proceed at not exceeding Medium Speed prepared to Stop at next Signal.
Name - Medium-Approach

Figure 10 A.R.A.
Indication - Proceed at not exceeding Slow Speed.
Name - Clear - Slow

Figure 11 A.R.A
Indication - Proceed at not exceeding Slow Speed prepared to stop at next Signal
Name - Slow - Approach.

Proceedings 1932.
Part 1.
Inset Sheet No. 1.

APPENDIX A.
SHEET 3.

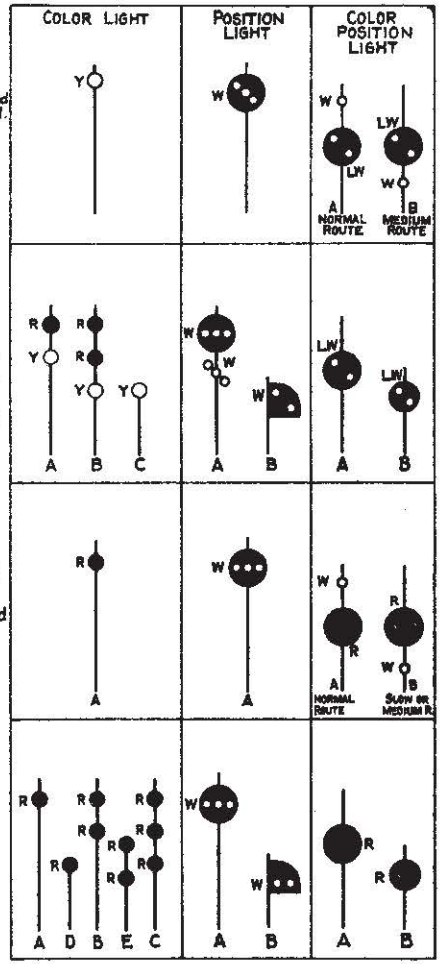


Figure 12 A.R.A.
Indication - Block Occupied, proceed prepared to stop short of train ahead.
Name - Permissive
Designate by Letter Plate or Marker Light.

Figure 13 A.R.A.
Indication - Proceed at restricted speed.
Name - Restricting or Know nothing.
Applied at entrance of Block to permit trains to proceed prepared to Stop short of Obstruction.

Figure 14 A.R.A.
Indication - Stop, then proceed in accordance with Rule 509-B
Name - Stop and Proceed
Designate by Number Plate or Marker Light.

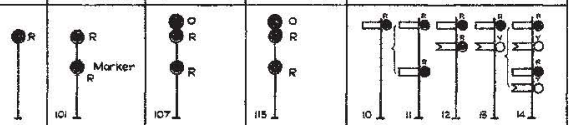
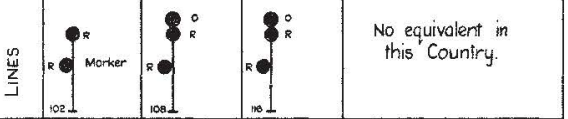
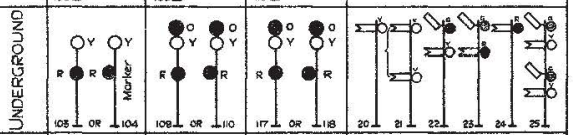
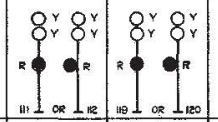
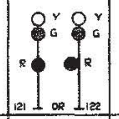
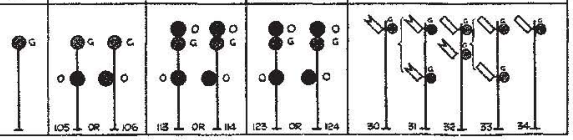
Figure 15 A.R.A.
Indication - Stop.
Name - Stop

COLOUR LIGHT SIGNALLING IN RELATION TO MANUAL BLOCK AND MULTIPLE ASPECT SIGNALS (BOUND)

Proceedings 1932.
Part 1.
Inset Sheet No. 2.

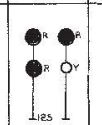
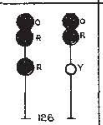
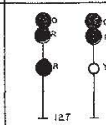
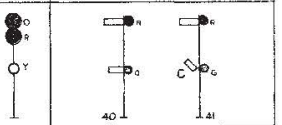
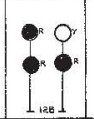
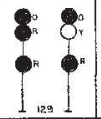
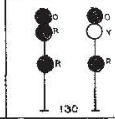
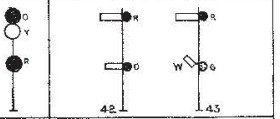
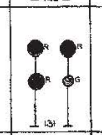
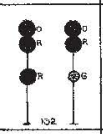
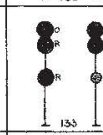
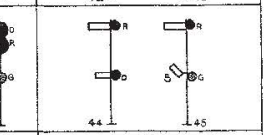
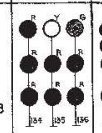
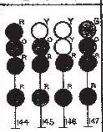
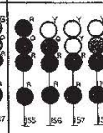
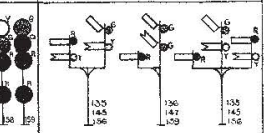
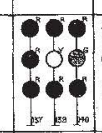
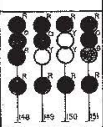
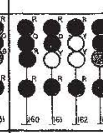
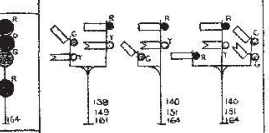
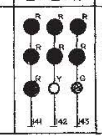
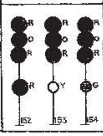
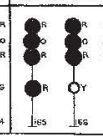
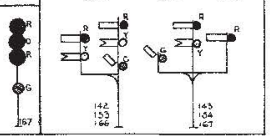
KEY R = RED
Y = YELLOW
G = GREEN
O = OUT

APPENDIX C.
SHEET 1.

COLOUR LIGHT SIGNALLING					
INDICATION		MULTIPLE ASPECT SIGNALLING			MANUAL BLOCK
	2 ASPECT	3 ASPECT	4 ASPECT	5 ASPECT	
RED – STOP (and Stay)	LINES				
RED – STOP (and Proceed)	LINES				No equivalent in this Country.
YELLOW – CAUTION RED Prepare to Stop at next Signal	UNDERGROUND				
YELLOW – ATTENTION YELLOW Pass next Signal at Restricted Speed.	CONFINED TO				No equivalent.
YELLOW – ATTENTION GREEN Pass second Signal at Restricted Speed.	SHOULD BE				No equivalent.
GREEN – PROCEED					

APPENDIX C.
SHEET 2.

KEY R = RED
Y = YELLOW
G = GREEN
O = OUT

COLOUR LIGHT SIGNALLING				
INDICATION	MULTIPLE ASPECT SIGNALLING			MANUAL BLOCK
	3 ASPECT	4 ASPECT	5 ASPECT	
RED / YELLOW – CALL-ON Proceed as far as the Line is Clear.				
YELLOW – WARNING RULE 5. R/R then Y/R by Check Contact				
RED / GREEN – SHUNT AHEAD When fixed on a Starting Signal, pass for Shunting purposes only.				
JUNCTION INDICATIONS – SPEED STOP – 134. 137. 141. 144. 148. 152. 155. 160. 165. PROCEED ON HIGH SPEED ROUTE – Prepare to Stop at next Signal – 135. 145. 156. PROCEED ON HIGH SPEED ROUTE – Pass next Signal at Restricted Speed. 146. 157. PROCEED ON HIGH SPEED ROUTE – Pass second signal at Restricted Speed – 158 PROCEED ON HIGH SPEED ROUTE – 136. 147. 159.				
PROCEED ON DIVERGING ROUTE – Prepare to Stop at next Signal – 138. 149. 161. PROCEED ON DIVERGING ROUTE – Pass next Signal at Restricted Speed. 150. 162. PROCEED ON DIVERGING ROUTE – 140. 151. 164.				
PASS AT LOW SPEED – LINE OCCUPIED – 142. 153. 166. See also 125. 126. 127. PASS AT LOW SPEED – LINE CLEAR – 143. 154. 167. see also 131. 132. 133.				

COLOUR LIGHT SIGNALLING IN RELATION TO MANUAL BLOCK AND MULTIPLE ASPECT SIGNALS (BOUND)

Proceedings 1932.
Part 1.
Inset Sheet No. 3.

APPENDIX E
SHEET 1.

KEY
R - RED
Y - YELLOW
G - GREEN
O - OUT

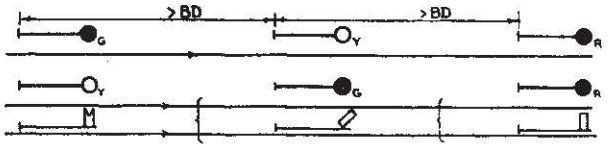


DIAGRAM 1.

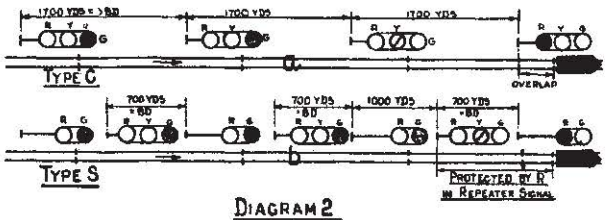


DIAGRAM 2

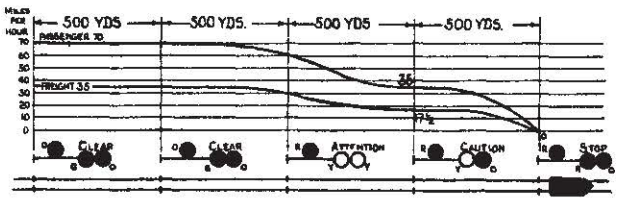


DIAGRAM 3

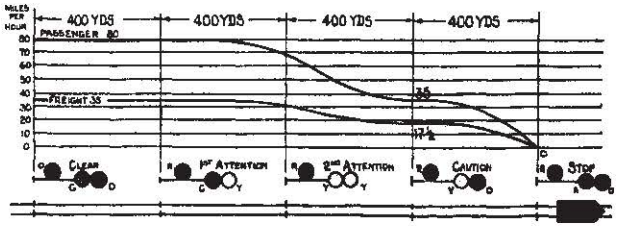
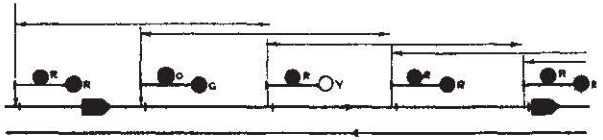


DIAGRAM 4

APPENDIX E
SHEET 2.

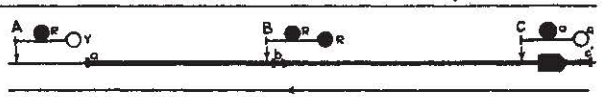
KEY R - RED
Y - YELLOW
G - GREEN
O - OUT



HEADWAY ON GREEN = 3BD+S+L

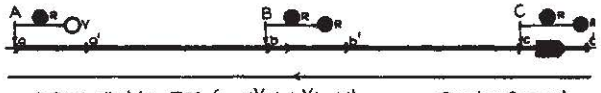
Where BD = Braking Distance
S = Sighting Distance
L = Length of Train

DIAGRAM 5



A Controlled by T.C. a-b
B Controlled by T.C. b-c
C Controlled by T.C. c-d

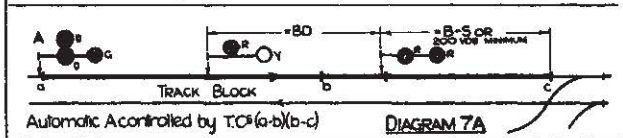
Overrun incorrect



A Controlled by T.C.s (a-a')(a'-b)(b-b')
B Controlled by T.C.s (b-b')(b'-c)(c-c')
C Controlled by T.C.s (c-c')(c'-d)(d-d')

Overlap Correct

DIAGRAM 6



Automatic A controlled by T.C.s (a-b)(b-c)

DIAGRAM 7A

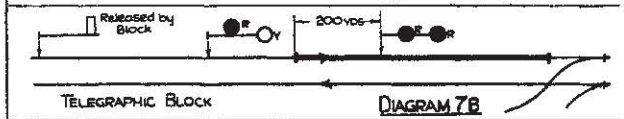
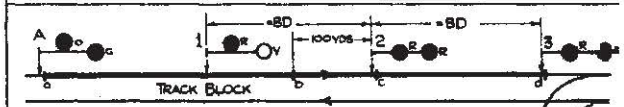


DIAGRAM 7B



Automatic A Controlled by T.C.s (a-b)(b-c)(c-d)
Cautionary Signal 1 controlled at R by T.C.s (b-c)(c-d)
Outer Home Signal 2 controlled by T.C. (c-d)
Where rear signal A is a controlled signal T.C.s (b-c)(c-d) need not be sub-divided.

DIAGRAM 8

COLOUR LIGHT SIGNALLING IN RELATION TO MANUAL BLOCK AND MULTIPLE ASPECT SIGNALS (BOUND)

Proceedings 1932.
Part 1.
Inset Sheet No. 4.

APPENDIX F.
SHEET 1.

KEY. R = RED
Y = YELLOW
G = GREEN
O = OUT

Assume BD between successive Signals.

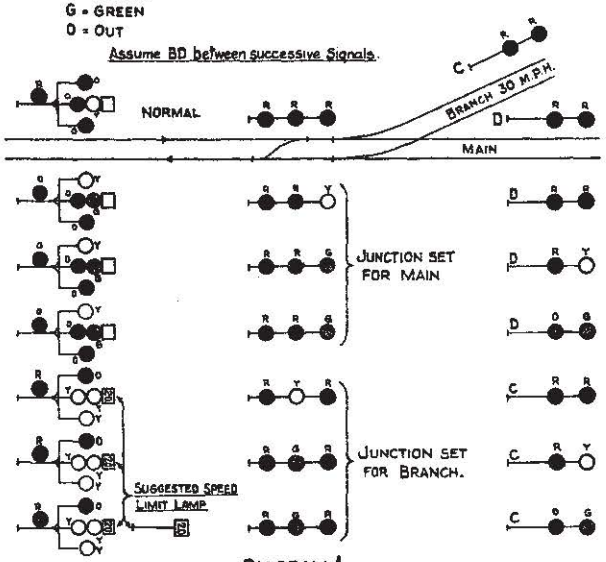


DIAGRAM 1.

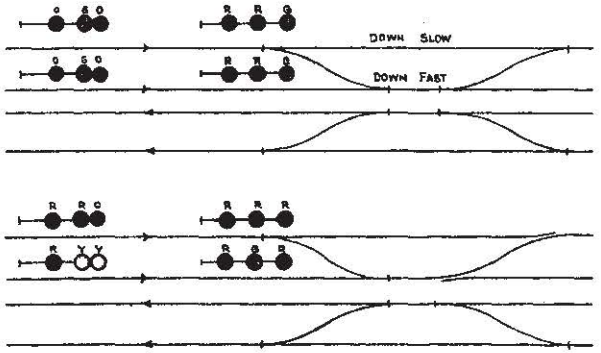


DIAGRAM 2.

APPENDIX F.
SHEET 2.

KEY
R = RED
Y = YELLOW
G = GREEN
O = OUT

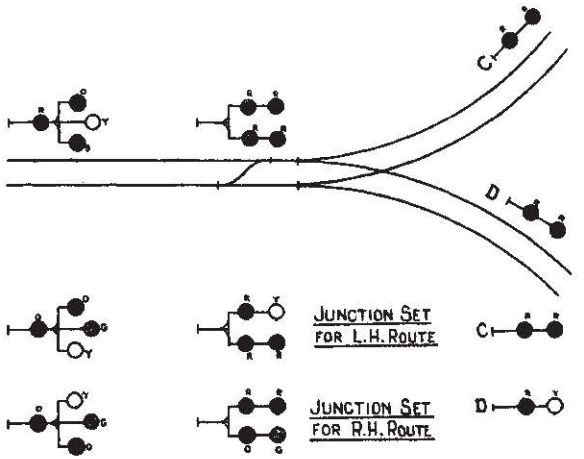


DIAGRAM 3

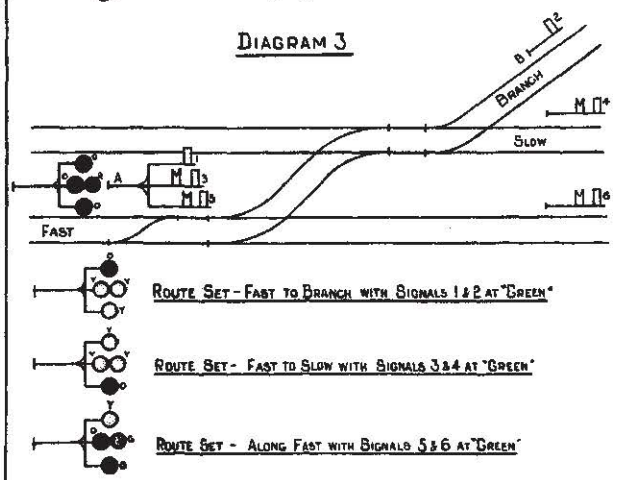


DIAGRAM 4

COLOUR LIGHT SIGNALLING IN RELATION TO MANUAL BLOCK AND MULTIPLE ASPECT SIGNALS (BOUND)

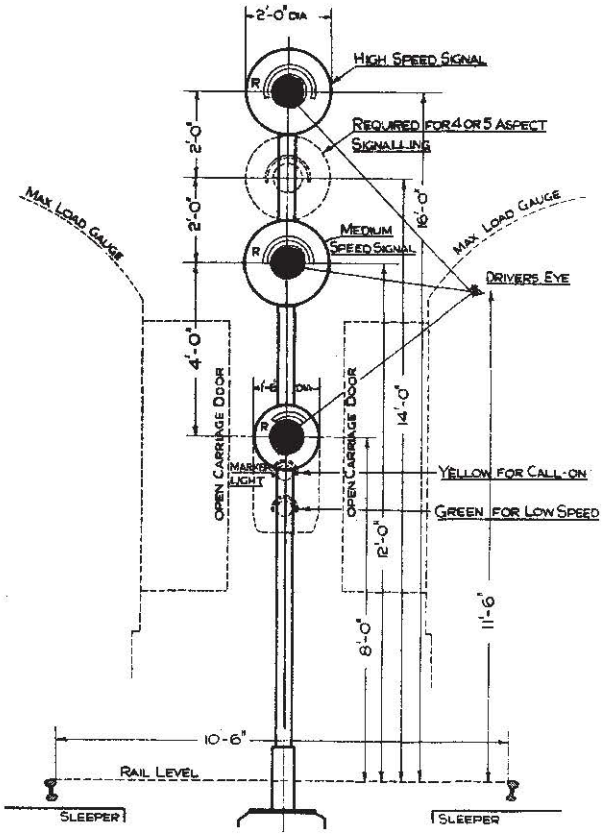
Proceedings 1932.
Part 1.
Inset Sheet No. 5.

APPENDIX H
SHEET 1

STANDARD HEIGHTS AND CLEARANCES

10 FT-6 IN. SPACE

SCALE ½ IN. = 1 FT.

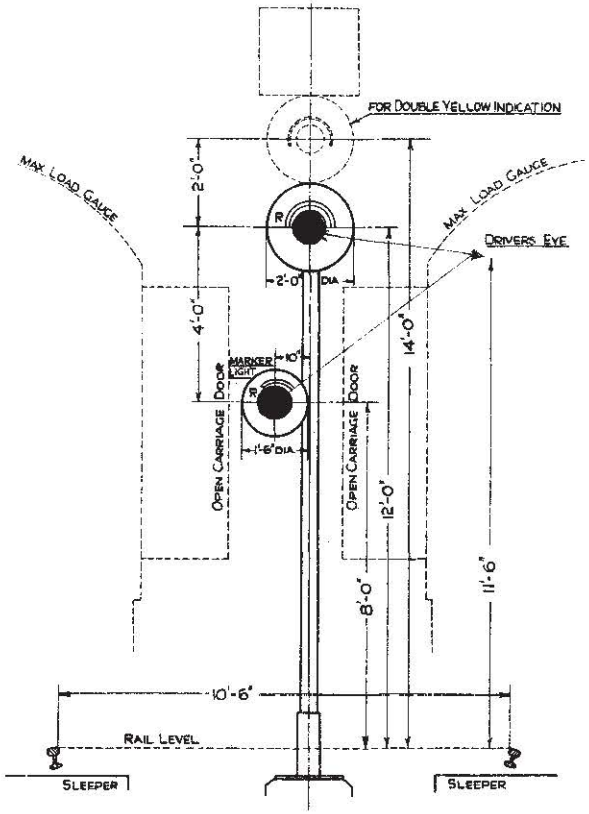


APPENDIX H
SHEET 2

STANDARD HEIGHTS AND CLEARANCES

10 FT-6 IN. SPACE

SCALE ½ IN. = 1 FT.

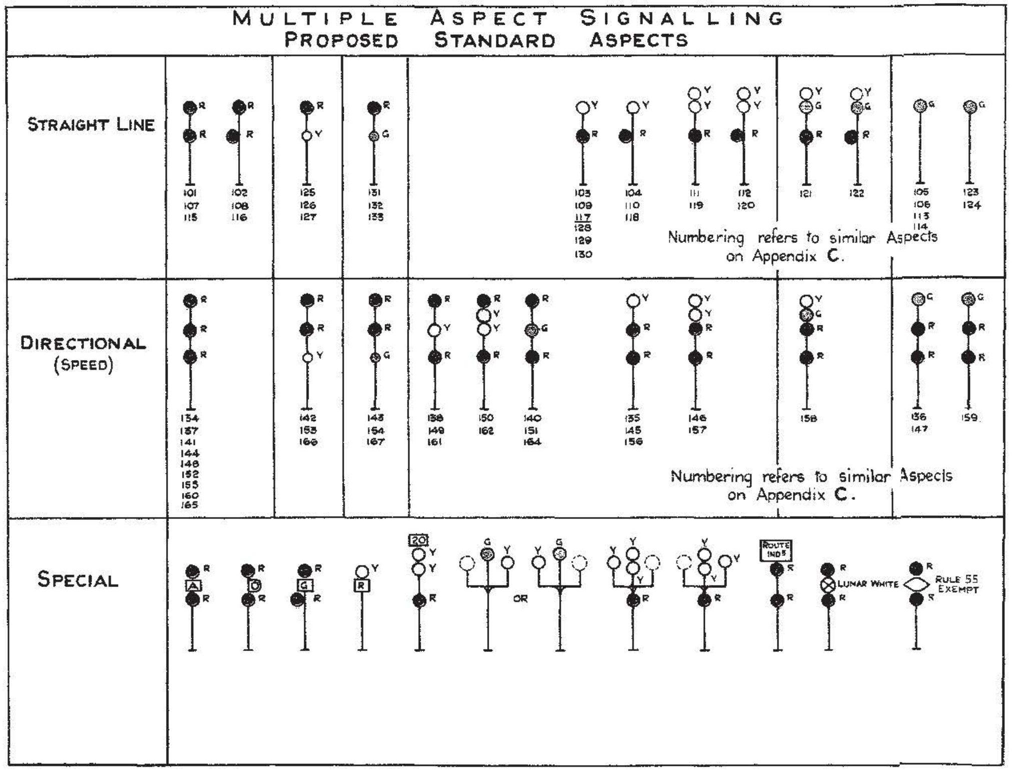


Proceedings 1932.
Part 1.
Inset Sheet No. 6.

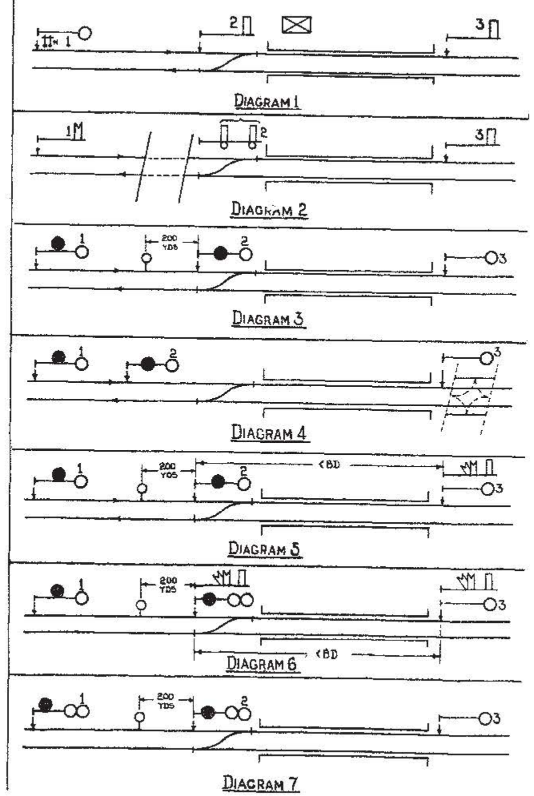
COLOUR LIGHT SIGNALLING IN RELATION TO MANUAL BLOCK AND MULTIPLE ASPECT SIGNALS (BOUND)

APPENDIX G.

KEY R - RED
Y - YELLOW
G - GREEN



APPENDIX J



APPENDIX K.

KEY
R - RED
Y - YELLOW
G - GREEN
O - OUT