Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Wednesday, January 8, 1969

The President (Mr. B. REYNOLDS) in the chair

The Minutes of the Technical Meeting held on December 4, 1968, were read and approved.

The President introduced and welcomed to the meeting Messrs. A. S. Cross, D. G. Howlett and B. M. Steele, who were present for the first time since their election to membership.

The President also welcomed members of the Institute of Transport to whom an invitation had been extended to attend the meeting.

The President then requested Mr. D. M. Howes (Associate) to read his paper entitled "The Operating Requirement of Modern Signalling".

The Operating Requirement of Modern Signalling

By D. M. HOWES (Associate)*

1. INTRODUCTION

Over the past decade we have witnessed a revolution in technological developments affecting railways in general, but in no field has the effect been more marked than in signalling. I go further, and suggest that the introduction of new signalling techniques and equipment has been achieved with very limited teething troubles and a high degree of subsequent reliability, considering the extent and scope of the change—a somewhat happier picture than has pertained to some other aspects of technological change.

As a layman addressing a professional technical body, there is a danger of assuming pseudo-technical knowledge. To avoid this pitfall, this paper is essentially written from a non-technical standpoint and is intended to range over the requirements of the user; how these are translated into a quantitive specification and how the production of the resultant signalling plan requires intensive co-operation between the Operating and Signalling Departments in a conscious spirit of flexible "give and take".

2. HISTORICAL BACKGROUND

The immense change from mechanical signalling to modern power signalling which has occurred, apart from isolated pockets, over the last fifteen or so years has, technical considerations apart, had a tremendous psychological impact upon the user. Viewed in retrospect, the traditional

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mechanical signalling which existed for so long can be seen to have suffered from:—

(a) Quite severe physical limitations imposed on working of signals and points.
(b) Prodigality in the provision of signalboxes.
(c) A high labour content.
(d) Uneven length of block sections, imposing artificial restrictions on headways and line capacity.
(e) The high degree of reliance on the skill and discipline of the signalman, who has only limited mechanical/electrical controls to assist him.
(f) Comparatively laborious and slow operation.
(g) The very small areas of control exercised by each signalbox, which did not help efficient train regulation and which demanded a very high standard of effective co-operation between large numbers of signalmen, and a cumbersome and expensive system of train reporting.
(h) Limitations on the capability of displaying a positive direction to drivers under certain circumstances, e.g., Rule 39(a)—Block Regulation 5 etc., and the need, therefore, to resort to time-consuming arrangements to caution or instruct drivers verbally or by the display of hand-signals.

There are doubtless other limitations which I have overlooked, but the Operating Department, and the signalmen in particular, learned to live with the situation, and over the years devised techniques which exploited the equipment to the best advantage and, in relation to train performance, with considerable success. However, on most trunk routes there are known difficulties and bottlenecks, and in recent years these have been accentuated by the increase in speeds and a wider speed band of trains, changes in the characteristics of train patterns, route rationalisation and concentration on fewer trunk routes, and other factors.

It is perhaps not surprising that, initially, operators were somewhat sceptical, in advance of actual experience, of the claims put forward for the operating advantages of modern power signalling, and in retrospect it might be claimed that some of the earlier power signalling schemes have proved to be over-elaborate and to have too many pairs of "braces" to go with the "belt". If so, this must be judged in relation to the lean years of operating frustration due to inadequate facilities, and thus the understandable human attitudes which can arise when the opportunity of a "new world" is offered. Having been critical of their own forebears, operators may be forgiven for having initially been at great pains to ensure that the next generation should not also be able to point the finger of scorn at the short-sightedness of present operators.

Perhaps I can make this particular point most forcefully by recounting a personal experience in relation to a signalling scheme in which I was directly concerned some years ago. This particular scheme was the first covering a long section of line, and the proposed area of control included three notorious bottlenecks where four lines reduced to two in a short distance, so that delay, particularly to freight trains, was of some enormity. As part of the resignalling scheme, I vigorously pressed for four-tracking to be carried out to eliminate the two-track bottlenecks, but in the event cost factors precluded this course. I was vehement about the consequences of what would seem to be a short-sighted policy and generally felt that the whole success of a costly scheme was being placed at risk. In the event I had to eat my words; not only did experience show that the extension of four-tracking was unnecessary, but indeed, some of the existing four-tracking might well have been eliminated.

Operationally therefore, a major re-adjustment of outlook and approach has been necessary in the light of growing experience of the practical value of modern signalling. This adjustment has been achieved, and out of all the lessons which have been learned, the following are perhaps worthy of special note:—

(a) The prime need for the operating task to be fully investigated and defined, due allowance being made for anticipated changes in traffic levels and characteristics over the life span of the scheme.
(b) Determination to simplify track layout and signalling by:—
    (i) Critically examining existing operating practices.
    (ii) Recognising that the existing train service pattern may, to some

trains in both these and intermediate speed bands. The difficulties experienced with the short-wheelbase, 2-axle freight wagons, leading to the imposition of a 45 mile/h. maximum speed over a very large slice of the total wagon fleet, have materially aggravated the problem. Although the introduction in recent years of modern wagons capable of speeds of 60 and 70 mile/h. is welcome as a first step toward closing the range of speeds, it is only when large-scale replacement of the wagon fleet has been achieved that the position will significantly improve. Even then, there remains the possibility, indeed the probability, of the speed of passenger trains being pushed beyond the 100 mile/h. barrier, and so the problem of speed differential is still likely to be a significant factor.

The mix of trains of varying characteristics is of obvious importance in relation to the signalling requirement, and there is little alternative but for this to be worked out in some detail, preferably on an hourly basis and certainly for the peak hour requirement.

4.3 Headways and line capacity

There are few aspects of signalling on which there is so much loose talk as line capacity. It is astonishing how many people seem to think that line capacity is something which is an absolute which can be identified in its own right and applied on a formula basis. In reality, until one has worked out the headway required and knows the mix of trains, the words have little meaning. In other words, it is a derivative rather than an absolute. The vital task is that of determining the headway required and here I think operators generally have still some way to go in establishing a uniformity of approach. The problem lies in the fact that most of our trunk routes carry trains of widely differing characteristics, both in regard to speed and braking capability. The number of trains of differing characteristics is also highly variable. We have the situation on some routes where the predominant pattern of service consists of high-speed express passenger trains, others which carry an intensive suburban passenger service, and yet others on which there is a wide scatter right through the speed bands.

As I see it the headway specification must be operationally assessed from a study of the pattern of train service and the speed and mix of trains. Some tolerance should then be added to cover any specific physical characteristics of the line, for recovery from delay and to provide an element of flexibility.

In my judgment headway should normally be expressed as (x) minutes at the maximum speed of the fastest trains using the route, although it must be recognised that there will be cases where it is sensible to relate headway to the speed of the largest group of fast trains, particularly in those cases where there are only a few services scheduled at very high speed.

The vital point the operator must bear in mind is that, having set the basic headway criteria, this conditions the headway applicable to trains either side of the datum line.

5. MATTERS REQUIRING JOINT EXAMINATION AND DECISION

5.1. Multiple-aspects—how many?

This is an issue which has given rise to considerable difference of opinion, with particular reference to the choice between 3- and 4-aspect signalling. There can be little doubt about the factors which need to be taken into account, viz.:—

(i) Maximum permissible line speed.
(ii) Physical characteristics of the line—gradients, junctions, loops, stations, crossings, siding connections, speed restrictions.
(iii) The particular requirements that arise with extensively-used commuter suburban lines with close spacing of stations.
(iv) The desirability of maintaining "parallelism" between signals on adjacent fast and slow lines in order to avoid sighting difficulties or misreading.
(v) The effect of the chosen headway criteria.
(vi) Avoidance of mixing 3- and 4-aspect signals.
(vii) The need to provide for "closing up" trains at the approaches to key locations.

In practice 4-aspect signalling will almost certainly be required in relation to the short headway necessary to operate an intensive suburban service. On trunk routes, over which there will always be a wide disparity between the upper and lower speed bands of trains, 4-aspect signalling is generally desirable, as the

degree, be dictated by the existing signalling limitations; and taking into account the removal of such limitations in assessing the future pattern of service.

(c) The need for strict discipline in planning, and the avoidance of second, third, and even fifth and sixth thoughts.

(d) The need for an adequate comprehension of modern signalling capabilities.

(e) The vital need for a meaningful and continuing dialogue between the Operating Department and the Signal Engineer.

3. OPERATIONAL OBJECTIVES

The operational criteria which must be reflected in the planning of any signalling scheme are:—

(a) Maximum degree of safety.

(b) Automated control of equipment, so far as is practicable, so as to minimise, from the safety standpoint, reliance on the human element.

(c) Simplicity of operation from the signalman's standpoint—(b) and (c) together will free the signalman as far as possible for the job of making operating decisions.

(d) The minimum number of different indications for signals, and the need for these, as far as possible, always to have the same meaning.

(e) The building-in of some margin to cover possible future changes in the operational task.

(f) Facilitating the maximum rationalisation of track, points, etc.

(g) Minimising capital and annual costs, but maximising reduction in annual working expenses.

In short, the signalling scheme must "safely and reliably encompass the total required operating task using minimum track facilities at minimum capital and annual costs and produce maximum savings".

4. FACTORS TO BE CONSIDERED IN ASSESSING OPERATING REQUIREMENTS

Signalling is expensive by any standards; once carried out we are committed for 20/25 years. These hard financial facts must, therefore, underpin the operating approach to the job of establishing the task to which the signalling must be fitted. An added point to emphasise in regard to the care needed in drawing up the operating specification is the overall financial picture facing British Railways from January 1, 1969, when investment funds, following recapitalisation, will be more difficult to find, and of course, the abolition of deficit financing will mean that the Board will have to live within its means.

What, therefore, are the basic factors that must be evaluated before technical planning is carried out?

4.1. Traffic Levels

The starting point must be an assessment in depth of the volume and character of both passenger and freight traffic likely to prevail in the area to be re-signalled. This straightway involves the marketing side of the organisation, who must be approached to provide an appreciation of anticipated future changes. Using existing traffic levels suitably adjusted to anticipated changes, judgment will still have to be exercised as to the level of traffic for which it is prudent to plan. There must always be a material element of uncertainty, as traffic levels, of course, can be affected by external economic factors which can change rapidly, and which no amount of foresight can adequately encompass. Prudence therefore requires that whatever level of traffic is finally selected, a margin must be allowed in the Signalling Plan for additional business.

4.2. Pattern of train service, speed band and mix of trains

The levels of traffic must be converted into a train service pattern which must reflect many factors, not least the extent to which the work load can be spread over the 24 hours; or, conversely, the element of peaking of trains which cannot be avoided.

The overall train service pattern itself is of little value without knowledge of the upper and lower speed bands for which signalling must cater, and also the mix of different categories of train. A besetting problem on British Railways, perhaps more than anywhere else in the world, is the very wide range of maximum speed of trains—today these range from 30/35 mile/h. at the bottom end to 100 mile/h. at the top end, with varying numbers of

spacing of signals necessary to give adequate braking distance for the high-speed trains would normally react unfavourably on the running of the slower-speed trains if 2- or 3-aspect signalling were employed.

5.2. Size of area to be controlled by the power box

If, as now seems clear, there is little technical limitation on the size of the area which can be controlled from a single point, why is this technical capability not being fully exploited? My own view is that, at any rate for some time yet, practical issues will determine the position —in moving from the situation of having a multiplicity of signalboxes it is in my submission important to avoid equating size, for its own sake, with optimum efficiency of operation.

Accepting that one of the greatest benefits of power signalling is unified control of movement over a considerable length of route-mileage, including stretches of dense trunk and local movement, together with "greenfield" stretches, it must be remembered that this benefit comes from the improved ability to make operating decisions based on greater and more precise knowledge of the "on line" position. The sub-division of the operating floor of the power box into a number of panel operators, who are co-ordinated by a Controller/Regulator, carries with it a limitation on the total number of persons whose activities can be effectively both co-ordinated and directed.

I believe there is a sensible limit to the number of operators who can be effectively co-ordinated by the Controller, and I think it is an over-simplification to suggest that as all the people are closely adjacent to one another, there would be no problem of co-ordinated action. I have heard it argued that to avoid this limitation we should organise the power box so that in effect there are two or even three or more separate teams of people, thus in fact simulating several power boxes all rolled into a single building. I find this difficult to comprehend, but in any case, there are other factors which enter into the issue. Among these is, I think, the fair argument that it is highly desirable that the traffic patterns over the routes encompassed in the power box area should have an affinity with each other, and that there is no merit in including lines which have neither physical nor any other practical connection one with the other.

So far as the cost implications are concerned, a number of recent schemes have been examined to ascertain the difference in capital outlay which would arise from a reduction in the number of power boxes, and in each case it has been found that this tends to increase. The most recent illustration of this is in connection with the proposed re-signalling from Weaver Junction to Glasgow. An examination was made to see whether one box to cover the London Midland Region portion would be a better financial proposition than the three which are proposed at Warrington, Preston and Carlisle. In fact, the one box solution would lead to a substantial increase in capital outlay.

5.3. Layout and Design of the Operating Floor of the Power Box

For practical purposes the operating floor could be underground or somewhere far removed from the physical railway. Sometimes I wonder whether, had we done this, we should have avoided some of the difficulties which have arisen, with particular reference to the degree of natural light provided, the position of windows, etc., which in turn have given rise to problems of layout of the operating panels and, in particular, the dimensions and nature of the train describer displays. The ability for men to see the railway outside cannot have more than a psychological value. This may be important, and doubtless medical opinion would argue strongly about the contribution to the health and alertness of signalmen, but frankly, I wonder just how real this is— in my submission the real psychological change for the signalman is that of moving from a situation of a very limited area of control to one where he is directly responsible for a long stretch of line.

5.4. Review of Track and Point Layout

A critical review of track, points, etc., must be carried out as an essential preliminary to the Signalling Plan. The approach must be to take nothing for granted but rather to challenge the continuing need for the existing number of running lines, loops, refuges, etc. It is here that an understanding of modern

signalling capabilities is so important, as only then is it possible that a sensible judgment, in relation to the Train Plan, can be formed in regard to physical facilities.

Simplification of complex point layout situations demands a deep examination of the movements requiring to be made, particularly those relative to conflicting movements; the sensible extent of alternative route provision; and the necessity for simultaneous parallel movements.

A particular aspect of the review must be the extent of provision of crossover roads—those for which there is a regular user—but, perhaps even more important, the requirements to cover emergency use—for example, single-line working—and to facilitate mechanised track maintenance. The spacing of crossover roads and whether they should be single or double, must be assessed. As a general rule-of-thumb approach, a spacing of around seven to eight miles has been found generally an effective compromise between cost and limitation of train delay. The particular problem of justifying double crossover roads, so that in the emergency situation any movement to and from a single line is made in the facing direction, thus obviating the need for trains to "back over", is most difficult, and must depend in considerable measure on the traffic characteristics of the line, and where applicable, the need for maintenance of overhead line equipment. A further facet of the emergency crossover situation is deciding whether the crossovers should be worked from a panel in the power box or be ground-frame operated with a release from the power box—in general, the latter course should be adopted.

A problem, continually increasing in complexity, for the operator, is that with further route rationalisation, which increases the track user of the remaining trunk routes, the provision of adequate weekday possessions for the Civil Engineer, in order that economic use can be made of the expensive track equipment, is becoming increasingly difficult. The bugbear is that on the two-track sections of main line conventional single-line working, even with all the aids we have so far been able to devise, is at best a slow business and a very substantial impediment to train movement. To provide for permanent two-way signalling of lines over long stretches of trunk routes is, on the basis of present technology, out of the question on cost grounds. Suffice it to say that one field in which the ingenuity of the Signalling Department is required is that of producing a low-cost solution to optimise traffic movement during both planned and emergency line possessions.

Siding connections must be reviewed in relation to the anticipated future of the point being served by this railway terminal or private siding. Finally, the review should determine which connections should be worked directly from the power box, which from ground or shunting frames released by the power box, and which should be divorced from any form of control from the power box and left for internal operation—I firmly hold the view that the latter should be maximised.

The end product of this examination is to maximise simplification and rationalisation of track and minimise the cost of re-signalling, not to mention the reduction in maintenance and renewal costs.

6. SOME COMMENTS ON FURTHER FACETS OF POWER SIGNALLING

6.1. Remote Control

One of the particular problems that arises from control of a large route-mileage of line from a single power box, and which, indeed, in some measure influences the size of the control area, is that of the outlying sections.

The earlier systems of remote control, although very successful considering they were an entirely new development, gave rise under failure conditions to quite serious operating problems in that the indications being given in the controlling box could not be wholly relied upon. It was thus not possible for the signalman to confine action to the particular "functions" which appeared to be the cause of the failure, and it was necessary to have recourse to extensive handsignalling and clipping of points, much of which, in fact, was unnecessary. Operationally it is vital that the indications given in the signalbox relating to individual points, signals, etc., at a remote interlocking should have the same integrity as when these are operated by "direct wire". In the most recent installations it is understood that this difficulty has been overcome, and that action can now be taken specifically in

regard to a particular failure. Operationally, provided experience proves the safety characteristics of the entire system of remote control, and if provision of "overriding switches" for key locations is adopted, this might very well obviate the need for emergency signalling panels at remote interlocking locations.

6.2. Train Describers

This is a question which has given rise to a good deal of argument and difference of opinion within both the Operating and Signal Engineering departments. Operationally the need is for a clear view of the train describer indications on the panel, and a particular problem is posed in this connection in respect of the Regulator/Controller, who is normally located to the rear of the panel and in a central position. The degree of natural light permissible has been a problem, and there are some boxes where signalmen have difficulty in identifying the number in the train describer indication panel. A further factor is the size of the signalling panel, as clearly the larger the train describer characters are made, the larger the panel must be. This has its own very substantial disadvantages, not only in the size of the working floor but in making the panel less compact and interfering with the ability of all panel operators to interpret the display as quickly as is desired.

It begins to appear that, in order to retain an acceptable size of train describer indication in relation to the overall length of the signalling panel as a whole, we must find other ways of providing the Regulator/Controller with the essential information which he requires to make a co-ordinated judgment. It would seem that the best compromise is likely to be the provision of a separate display for the Regulator/Controller which can provide an "on demand" copy of key sections of the signalling panel. This is clearly a feature which requires a good deal more examination and probably experiment, and while this may result in some marginal cost increase, there is little merit in spending a vast sum of money on signalling if we then impair the quality of the operating decisions, which are the end product of the facilities provided.

There are two other aspects of the train describer problem. The first is that there has been difference of opinion as to whether the train describer indications should be shown on the signalling panel or on a separate panel. I hold strongly the view that the proper system is to show the train describer indications on the signalling panel, located at the signal berths appropriate to the position of the train.

The second issue is that a good deal of thought is being given to possible ancillary use of train describer equipment. Operationally it is felt that if the system could be harnessed to provide also a system of train recording, this would be a most valuable management tool. Inevitably the train recording print-out could only embrace selected points in the power box area, but these could be made quite adequate for retrospective managerial use. If train reporting information could also be printed out in a limited form to Control Offices, much of the recording which is now necessary at these points might very well be eliminated. Moreover, punctuality information could be printed out covering any period required and in almost any form.

A possible further ancillary use of the train describer equipment, for which there would be an operating advantage, is for automatic train announcing and automatic operation of points at remote junctions. In the latter connection of course, it would be necessary to ensure a very high standard of reliability, and it must also be asked whether automation of remote junctions can be made satisfactorily to take the place of the skilled judgment exercised by the signalman in relation to situations created by train delays, out-of-course running, etc.

6.3. Standardisation of Signalling Equipment

A good deal has already been done jointly by the Operating and Signalling Departments to agree standard signalling practices on which standard equipment can be based.

There would seem to be an obvious advantage in maximum standardisation as this should lead to a reduction in first costs, perhaps speed up the detailed planning processes, and lead to simplification of maintenance and fault finding techniques, which clearly is highly desirable from the operating standpoint. A further facet of standardisation is that training of signalmen, and I assume

signalling technicians, is facilitated and training schedules can be simplified.

Earlier in the paper I have touched on the prime need for signal indications to have always the same meaning, and this is particularly important from the driver's standpoint. With the increasing degree of inter-running between Regions, it is obvious that misunderstanding will be minimised if signal indications mean the same thing everywhere in like circumstances. The same argument holds good for design and standardisation of ancillary equipment such as signal post telephones, ground frames, etc. If we work on a common basis throughout the system, train crews will always know what to expect.

Despite the degree of standardisation which has already been approved, it might be argued that too high a degree of permissiveness has been written in, largely to meet the operating argument of tailoring equipment in particular locations to suit special circumstances. Clearly in each case there must be a balance of advantage between standardisation and some loss of flexibility at particular locations. In striking the balance the effect on costs must be a significant consideration.

6.4. Alternative power supplies

Although power signalling schemes have included standby generators for alternative power supplies in the event of the main supply failing, experience has tended to show there have been far too many cases where the alternative supply has not functioned as planned, either in that it has failed to come in at all, or it has failed shortly after being brought into use. This is a most critical issue in terms of operating implications and is a matter which would appear to repay further investigation.

7. SIGNALLING FOR LOW-DENSITY ROUTES

There has been growing emphasis in recent years on track rationalisation to bring our facilities more directly into line with the traffic commitment. The new Transport Bill, in relation to the grant for surplus track, has particularly underlined the need to streamline track facilities, and provides financial support for a period of five years whilst identified surplus has to be carried until such time as it can be physically removed.

The upshot is that there is a strong probability of a considerable number of existing 2-track sections of railway being singled. This situation brings with it the need for a re-examination of the conventional methods of signalling single lines so as to provide a system which is cheap to operate but which will adequately encompass the traffic pattern envisaged.

I am not suggesting that traditional methods of controlling single lines are necessarily no longer applicable, but all these are relatively expensive in signalbox provision and limited in the line capacity that can be created. This limitation holds good whether electric token working, train staff working, etc., is used.

Over the past two years a modified form of controlling single lines has been worked out between the Chief Signal Engineer and the Operating Department which rejoices in the name of Tokenless Block. Under this system the delay which arises from having to stop to exchange a token is eliminated; the number of intermediate signalboxes may be reduced, and at those retained, men can be productively employed on other work without having to remain permanently in the cabin, and this has gone some way towards meeting the operational need. However, difficulties have been experienced because the system involves the retention of sections of double line, and the location and length of these, in relation to an acceptable degree of tolerance for out-of-course running, can become a critical factor. Suffice it to say that in my view further research is required to bring us nearer the aim of providing for a cheap, safe and flexible system for controlling single lines.

8. IMPLICATIONS OF ANY FURTHER INCREASE IN MAXIMUM PERMISSIBLE TRAIN SPEED

Considerable research is taking place into the possibility of going beyond the present 100 mile/h. speed limit. Many considerations enter into this proposition, but among the more important is the maximum speed at which it would be reasonable to expect a driver to operate under conventional modern signalling.

A detailed investigation has been carried out on the basic assumption that if speeds

in excess of 100 mile/h. are to be run, the necessary improvements in track, traction, rolling stock, braking systems and so on would be effected, and the equipment would be available.

Calculations were made of the time available to a driver between the sighting of signals and taking action. Assuming 300 yds. sighting of a signal as being generally available, the time in which a driver has to initiate any necessary action in respect of an adverse signal indication is as follows:—

at 100 mile/h.—6.1 secs.
at 125 mile/h.—4.9 secs.
at 150 mile/h.—4.1 secs.

Further calculations were made on the basis of maintaining maximum speed under adverse weather conditions, the normal sighting distance of the signal not being available and the driver receiving the first indication when passing over the A.W.S. inductor, which is normally 200 yds. on the approach side of a signal. The available driver reaction time then becomes:—

at 100 mile/h.—4.1 secs.
at 125 mile/h.—3.3 secs.
at 150 mile/h.—2.7 secs.

Any assessment of the minimum driver reaction time which should be available must be very much a matter of subjective judgment of variability between individual drivers; but assuming reaction time is composed of sighting the signal, identification, verification, interpretation, decision, and translation into action, then, as a general rule-of-thumb 3 secs. should be regarded as a minimum. The first point which emerges from this study is that the position of the A.W.S. inductor would need to be re-sited further in rear of signal.

Another particular issue which arises is the fact that a driver is required not only to observe fixed signal indications, but also the track in a general sense, in regard to people and obstructions which may be present. He also is required frequently to scrutinise the control indications on the driving panel of the locomotive. A driver is, therefore, constantly re-focusing his eyes from looking forward along the track to looking down at the instrument panel through an angle of about 60°. Ability to re-focus and the time taken to do so vary considerably according to individual characteristics, but medical evidence has indicated that the time can be as much as 3 secs. The situation can be greatly improved by raising the essential instrument indications on the driving panel to a higher level than at present, so that the angle of deflection between looking forward and looking at the instruments is reduced to, say, 30°—which medical evidence suggests is better than maintaining the eyes on a constant plane.

Again, much could be done to assist the position by attention to design detail of driving cabs of locomotives, with particular reference to:—

Noise insulation
Ventilation
Heating
Windscreen washers and wipers
Seating
Method of instrument display

The general view which has been reached is that, whilst there is a need for a much more detailed examination of the many facets indicated above, it should be possible for the various driver aids to be developed to a point where speeds up to 120/125 mile/h. can be encompassed under conventional signalling. Beyond this speed the problem becomes much larger and solutions more difficult, and it seems certain that automatic speed control of the locomotive would be an essential prerequisite.

9. WHERE NEXT?

Although modern signalling, as we know it today, is probably still capable of further technical development, it is pertinent to ask whether it will continue to be suitable for the railway of the 1980s and beyond. Much, of course, will depend upon changes in the nature of the operating requirement. These cannot, at this stage, be spelled out, but the indications seem clearly to point to higher-speed services. I believe existing signalling methods are capable of being developed to meet this situation—certainly up to 125 mile/h., provided the points mentioned in Section 8 are satisfactorily developed.

No doubt everyone is aware of the detailed study that is being carried out of a new signalling system based on track-to-train communication and commonly known as the "wiggly wire" system. I have been closely associated with this study—to which there is a counterpart being developed under U.I.C. auspices—

and at this stage judgment must be reserved. It would be presumptuous of me to comment on the technical issues, but from the operating standpoint the criteria must be:—

(a) Before introduction the system must be proven in terms of safety, reliability and flexibility.

(b) Cost must at worst be broadly in line with existing modern signalling.

It is understood that the equipment required for conventional modern signalling will still be needed for this new system, except the fixed signals themselves, and in addition there is the continuous permanent conductor wire which will be laid in the 4-foot. An in-built feature of the system will be the continuous monitoring of speed, with a visual display to the driver of both target and actual speed, and overriding control of the brake should a driver exceed the target speed indication shown. The system would, of course, obviate the necessity for the existing A.W.S. equipment and also the Driver's Safety Device on traction equipment. It is claimed that the system will optimise line capacity and, indeed, be capable of development into a form of "moving block". I have consistently challenged the value of moving block, which, as I see it operationally, would only be practicable on open stretches of line where its value is minimal in terms of real time; for in junction areas, where precedence of trains must be related to prevailing minute-to-minute circumstances, it would have little practical value. One advantage of the proposed system is that not only would it be suitable for existing speeds, but if successful, for any likely order of increased speed.

However, there are a number of important by-products that may very well become available as a result of the system, the most important of which is speech communication between members of the train crew and between the train crew and control and other points. There are material operating advantages to be gained from this facility in terms of minimising the effect of delays; the application of Rules and Regulations and the provision of meaningful information to the travelling public.

Suffice it to say that the proposals are clearly worth developing fully to the point where a proper evaluation can be made, in relation to conventional signalling, of cost, reliability and operating advantages.

10. CONCLUSIONS

I have attempted to outline the framework within which the operating approach must be made. It is necessarily brief, and moreover, in some places I have deliberately "trailed my coat". I have laid great stress on the necessity for and the way in which the operator has moved from expressing his requirements in general, somewhat amorphous terms to a quantiative and definite approach, and I do not think this can be over-emphasised. There is little merit in criticising the product if the manufacturer has been left to guess what is required. The challenge to technical ingenuity in recent years has been great and certainly will be equally great in the next decade. The operating approach must match technical developments and must continue to develop its own disciplines, not least to remember that "perfection may be the enemy of the good.

May I conclude on the note of cost? No matter how desirable re-signalling may be, it will only be achieved provided it is financially worth while. The search for reducing capital cost of equipment on the one hand and practical limitation of requirement on the other, must be relentlessly pursued. Moreover, there is a need for the savings which arise under modern signalling to be more effectively evaluated. The majority of operators would agree that there have been real financial savings arising over and above those which have been directly attributed to a scheme during the planning and submission stages; not least of these is reduction in train delay, with which goes the provision of a more reliable service for our customers. So far we have not been able to find an acceptable way in which these can be fully translated into money values.

11. ACKNOWLEDGMENTS

The author acknowledges the kind permission of Mr. W. O. Reynolds, Chief Operating Officer, British Railways Board, to read the paper and recognises the help given by a number of colleagues.

DISCUSSION

After reading his paper, Mr. Howes showed a film taken in the cab of an electric locomotive on the main line from Euston, and varied the rate of projection to show the effect on the driver of travelling at speeds of 100 mile/h and above.

The President then called on Mr. W. O. Reynolds, Chief Operating Officer B.R.B., to open the discussion.

Mr. W. O. Reynolds expressed his appreciation of being invited to speak, particularly as he was only a guest of the Institution.

He agreed basically with all that had been said in the paper by Mr. Howes. This was perhaps just as well, otherwise Mr. Howes or himself would be looking for a new job, and he hoped it wouldn't be him! There were, however, some of Mr. Howes' points which might be given further emphasis. These were as follows.

With regard to the planning of the scheme, he suggested that planning a signalling scheme could not be done in isolation; it must be part of what was now fashionably referred to as the "corporate plan". Signalling, after all, like many other things, was a tool of management. It was no use specifying the tools until one was quite certain what the product was that one was required to fashion. Except in the most exceptional circumstances, their product would be a mixture of passenger and freight services, and they must know in detail the range of the services, with their speed and cost characteristics, which were required to operate over the lines that were going to be resignalled. And in considering the passenger and freight services, they would go back still further, right back, in fact, to the whole of the railway activities. They could not plan the signalling just in isolation; they must know the whole of the plan because on that depended their financial position. And from the financial position came, of course, the money that at the end of the day was going to finance the signalling scheme.

His second point was the definition of headway. He was very pleased to hear Mr. Howes' remarks on this. Mr. Howes quite rightly made the point that there had been far too much loose talk of headways. In his own view, for each scheme the capacity of the line should be tabled in at least six different ways, with high and low ranges of trains at constant speed and a certain number of mixes of various classes of trains. He did not think that this should now present any computer difficulty. They had put 1 800 varying situations on the computer for their freight plan and he was quite sure that a computer would produce the answers on headway; it would say exactly what they could do in the terms that they were asking, of so many passenger trains and so many freight trains at various speeds; thus they could be told exactly what signalling they required for the business.

The next point related to 3- or 4-aspect signalling. There were undoubtedly some lines which might be more economically signalled with 3-aspect signalling but he suggested it should be considered whether the benefits of a relatively small amount of 3-aspect signalling might not be outweighed by the greater benefits they would get through standardisation on 4-aspect. He preferred now to regard 4-aspect as a standard, and 3-aspect as a one-off job that had to be justified.

On signalbox design, he agreed there was a need for more medical research into the desirability of giving signalmen a view rather than working in a windowless room. He certainly subscribed to the view that it was desirable for the signalman to be able to see trains, and he thought from time to time they needed someone to see trains, and if it was not the signalman he was not quite sure who it was going to be.

In connection with design, they also wanted to consider the design of the panels and the siting of the panels, and whether the man sat or stood. They might be interested to know that some research on this subject from the medical point of view was initiated in Scotland in considering the new boxes there; he did not think it was completed yet—a good deal of work was still being done on this relationship between design and the things the man had to do, and how much he could take in at one time; the optimum

size of the panel, and the optimum amount of information that could be given on the panel.

With regard to possessions for engineering work—he considered that for years they had given an inferior service to their customers through the demands of their engineering departments at weekends. This had always seemed to him to be quite out of line with what was done in some other railway administrations. And in addition they were doing work at a time when it was most costly in terms of manpower. They certainly needed a greater degree of sophistication in their signalling —more track work being done throughout the week and without inconvenience to the travelling public. He thought they had a good deal to learn from Continental administrations in this field.

Perhaps his most important point concerned standardisation. His view here was that neither the signal engineers in the railway service nor the signal engineers in industry, nor the signal engineering industry itself, had gone anything like far enough in standardisation. In saying this he was not advocating standardisation simply for the sake of standardisation, but because with standardisation should come some cost reduction. And this was a vital factor today. If they were to signal their railway properly in a modern fashion, then they must be able to do this much more cheaply than they seemed able to do it at the present time.

As to the future, he saw progress being made in two phases. The first was to meet the need to replace their existing outmoded semaphore signalling and to replace the earlier colour-light installations, and in that field it was a sobering thought that colour-light installations still regarded as almost modern were now forty years old. There was still a lot to be done in this field and he thought the pattern was fairly well established. This type of signalling struck him as particularly well suited to British conditions—particularly the high-density routes on the one hand and the more sparsely-trafficked routes on the other.

The second generation of signalling, to follow this, he thought, should be the development of the "wiggly-wire" system, i.e. a development of the Victoria Line principles for high-speed running. This type of signalling would be particularly applicable to those lines which carried a greater proportion of high-speed traffic. They must certainly never stop research and they must always look for the benefit in innovations, but new methods must prove themselves economical, and he came back here to this question of standardisation to keep down cost. He suggested they should all look for some means of cheapening the cost to the poor operator, because it was only then that he could justify the large-scale introduction of new signalling methods.

And finally, might he make a plea for one thing that Mr. Howes, strangely enough, omitted because he heard of this from him every day? He thought he might have heard from him about it that night—it was a plea for greater reliability. If he said that something between 8 and 10% of train delays today were due to failure of signalling equipment, this covered signalling equipment in the widest sense. It included a proportion of equipment that was really civil engineering equipment, but associated with signalling; but it was not civil engineering rail failures, nor rail breaks, nor was it mechanical failures. Signal and track circuit failures accounted for something like between 8 and 10% of their train delays, a very substantial figure. So in all their new equipment he hoped they would be able to build in a greater degree of reliability than they had at present. He was very conscious of the great strides that signal engineering had made to help the operators, but he still thought there was more that could be done to help them further yet, and he was sure the signal engineers could do it.

The President said he understood Mr. Howes had accepted Mr. Reynolds' contribution without the need for reply. (Laughter). He therefore called on Col. McMullen to give his contribution to the discussion.

Col. D. McMullen said he thought Mr. Howes had produced a paper that was badly needed, and he had produced it extremely well.

There were some points he would like to make—some others had already been covered by Mr. Reynolds.

In Section 3(d) Mr. Howes gave one operational criterion as "the minimum

number of different indications for signals, and the need for these, as far as possible, always to have the same meaning". From a safety point of view that was absolutely vital. To a driver a double-yellow must mean that the next signal ahead of him would be at yellow and not, perhaps, at double-yellow. And when he passed a yellow signal it must mean that, at that moment, the next signal ahead of him was at red and not possibly at yellow. He knew that they endeavoured to accept this principle as far as possible; if it was accepted, he was suggesting that it was not really objectionable to intermix 3- and 4-aspect signalling. After all, a driver was not likely to mistake a single-yellow for a double-yellow, and if he mistook a double-yellow for a single-yellow it did not really matter, anyway from the safety point of view.

He would, like Mr. Reynolds, take issue with Mr. Howes about burying his signalmen under ground. He was quite certain that there was a psychological, a very important psychological point, in this. Apart from that, Sir Michael Barrington-Ward always used to refer to the signalman as the policeman. He could not now exercise the functions of a policeman, though it was not so necessary because they were providing hot box detectors to take the place of signalmen in detecting hot boxes. Nevertheless, he did think it necessary both for signalmen to see trains from time to time, and for train drivers to see signalmen too.

One plea he would make was for the better soundproofing of operating floors. In one very modern box he went into recently, it was impossible to hear oneself speak when a train went past. As to whether a signalman should stand or sit while operating the panel, a point Mr. Reynolds had referred to, he had seen a good compromise in the Newhaven box in America. Two signalmen were operating a very long panel indeed, and each sat on a chair with wheels on its legs. There was a little rail along the front of the panel and they just whisked themselves along from one side of the panel to the other. It was done very quickly indeed.

Mr. Howes had said that the cost of signalling for two-way working was really out of the question and he would like to ask whether that really was so. After all, a 3-line track with one line signalled both ways must be cheaper in the long run than, say, a 4-line track, or a 2-line track —both lines being signalled both ways, again very much cheaper than a 4-line track. "Banalisation", as it was called on the Continent, was expensive, but he wondered whether it would be practicable to cheapen it, possibly by increasing headways when trains were running in the wrong direction on, say, one line of a double line. He did not know whether this would be possible or not. If it was a question of maintaining the parallelism of signals, he wondered whether the intermediate signals could be made into, say, automatic distants.

He had been extremely interested to see the film which Mr. Howes had shown, and was rather surprised that the time between signals, even at the very high speed, was as great as it was; and they did not seem to "come on one" nearly as quickly as he had expected them to. But what he thought really would shake a driver was the speed at which everything else was going past him. The overhead structures, which he believed were only about 200 ft apart, and bridges and everything else like that seemed to absolutely "whizz" past. This might be a strain on a driver and he would need something, as Mr. Howes suggested, in the way of automatic control to take charge in case that strain became too much for him.

Finally, he would like to make one point about the financial aspects of schemes. It had, he knew, already been covered but as Mr. Howes said, he had got to satisfy his masters, the accountants. As they knew they had got some other masters to satisfy as well as their own accountants. One of the great difficulties was in evaluating all the benefits that they all knew came from modern signalling. These were of immense value. The better service to their customers, that had been mentioned, and innumerable other benefits came from this. One got much greater efficiency all round as a result of better morale—better morale among signalmen, among drivers, and among station staff. And, of course, one got greatly increased speed of movement, not just of trains running on the main lines, but of movements in passenger yards, of cross movements, etc. He thought the very greatest endeavour should be made to try and evaluate all

these very well known and accepted benefits, because it would then make it much easier for them to justify their signalling schemes, which were so expensive.

Mr. D. M. Howes replied that he would not attempt to comment on all Col. McMullen's points. On the question of whether the signalmen should be underground or able to see out, this was very much a matter of personal opinion. There was at least one precedent he knew of on London Transport where the signalmen sat in four walls. He did not feel terribly strongly about this, but he did say quite specifically that provision of the capability of looking out had brought about a lot of design problems on the working floor of the box. On soundproofing he would go with Col. McMullen wholly. He thought there was a need for improved acoustical properties on the working floor, but again one of the snags here was that some of their powered boxes had become architectural edifices with substantial escalation of costs. There was a need to keep the thing within bounds, but they must make sure the money was spent on the important things.

On two-way signalling he was not really sure whether he thoroughly understood Col. McMullen. In the written paper he was using the term in the context that they could not afford to provide permanent two-way signalling on their main lines simply to enable them to minimise the effect on train working during—for instance—mechanised track maintenance, possessions and the like. If—as was done in some places, to quote Col. McMullen's illustration—there were tracks with a bi-directional third track in the middle as for instance applied in certain parts of France, this was where one had basically a predominant regular flow in one direction for a limited period, and reversing at the other end of the day. These conditions did not apply in the same degree in the U.K. and he doubted very much whether they could ever face the very material additional cost of building into signalling schemes the capability of working either way over virtually any pair of metals.

On the high speed film, and Col. McMullen's point about the effect on the driver of the lineside buildings and so on, he did make special reference to this. He found when they first ran this film throughout, when it went on for a longer time than as shown that night, he was screwing his eyes up at regular intervals, and he could well imagine that if he were on the footplate of a locomotive driving, say, 200/300 miles, this would become a very considerable strain indeed, particularly if one remembered that a driver was not only looking for signals, but was also required to look ahead at the track generally, and was also required to look from time to time at his essential control indications.

On cost he wholly agreed, and he had ended, they would remember, on the note that there was a need for the operators to look once again at how better they could quantify the savings that accrued from modern signalling. There were significant savings of which they were fully aware; their problem had been a way to satisfy the financiers of the world by expressing these savings in a way which they would accept. There were really two specific aspects; first the direct savings in terms of improved speed and reduced delays, and secondly the extent that signalling contributed to improved reliability and thus the attraction of additional business.

Mr. J. H. F. Tyler remarked that it was not often that a senior operating man gave the Institution a paper, but when he did it was always of the greatest interest to them because they had an opportunity of discussing signalling and operating matters in principle, unhampered by the requirements of a particular scheme.

Mr. Howes' paper had been an extremely interesting one to him because it touched on so many things that were in their minds at this time.

He would begin with a note on what Mr. Howes said so far as the limitations of mechanical signalling were concerned; he thought he expressed a view here for most of the signal engineers in saying they felt that the signalman in a busy mechanical signalbox had a far more arduous job than the panel box man. That should not be forgotten. The panel box man was fully protected against making a mistake and he had all the information in front of him; he was assisted by a controller who could instruct him in the event of the traffic not running according to plan; he could make unscheduled crossing movements much more easily than the man in the mechanical

box because he had so much more information.

Under "Operational Objectives" Mr. Howes rightly considered that there should be as much automation as possible and, of course, that the operation should be as simple as possible. The speaker entirely agreed, but would suggest that consideration should once again be given to the automatic release of the route after the train had passed. Mr. Howes would remember that some years ago this proposal was put up and turned down by the operating side (they never knew why). There were certain difficulties in doing it but nevertheless he felt it was an operating advantage which shouldn't be lost.

On their side, perhaps, he wondered whether they might not see if they couldn't introduce preselection, because the machine operated so much quicker than the man. The signalman could set up the second route and go away and do something else. This was a matter which should still be thought about.

He did not want to go into the question of headway in any length. It had been mentioned two or three times already; but could he say to the operating side that all they had to do was to tell the signal engineer what they wanted, and what traffic was to run, and he would interpret this into headway? Headway must always be associated with speed, it must also be associated with non-stop or stopping trains.

On the size of the area to be controlled, Mr. Howes said no rules had yet been established. Areas were getting bigger and bigger, and there wasn't a technical limit. But there should be something to say where to stop. He did not think they should leave it, because they were putting in equipment which was going to last for 25 or 30 years, and they ought to decide now the rules for this sort of thing.

Another thing which they should do was to set down O & M-wise the precise duties which Mr. Howes expected of his signalmen, and of his controllers. What was their function and responsibility. Did one expect the signalman to do any controlling or regulating, or did one not? Was he a button-pusher or wasn't he?

A point about lighting which had been mentioned was interesting because at a number of signal boxes that he had had something to do with, dimming switches had been put in for the lighting, which could be put right down to practically nothing, leaving the panel with all the indications on it very, very clearly displayed. But could they get the signalmen to do that? No, the signalmen wanted to have the lights as bright as possible. It might be that they could help the operator here by deliberately arranging the lighting so that the panel was kept more or less in darkness, when the indications would show up well, and have only reading lights elsewhere.

Lastly there was this question of high speeds, and again it was an enormous subject to have to go into, but on the signalling side they were more than a little concerned about it. When one considered a 50-mile journey, and a 150-mile/h train following a 75-mile/h train, the first train had to be 25 miles away or half way on its journey, before the other one could start, unless there were loops or quadrupling. Did this not mean that if they were going to have a comparatively few—he suggested it would only be that—150 mile/h trains, then they would probably have to put back some loops and quadrupling that were now being taken out?

He was also very interested to know that the Tokaido line, which only ran at 125 mile/h, had a "six foot", which was in fact, he thought, nine or ten feet. He also understood that the tunnels had to be flared. If they were to run trains at 150 mile/h, it seemed that the six-foot might have to be widened for the shock wave of two trains passing at 300 mile/h.

As a last point, the question of signalling failures, remarked by Mr. Reynolds, he would only say that they recently made a survey, as Mr. Reynolds knew, but the interesting result was that in a number of cases the failures were going down and yet the delays were going up.

Mr. Howes agreed wholly that in mechanical boxes the job of the signalman was much more arduous. But relating that to the other point Mr. Tyler had made about the signalmen's duties, what was one really looking for from a signalman? He would say that the real comparison today was that in the mechanical box, even the busy one, the control area was still relatively very small, and so one left a degree of physical effort

which was not present in the panel box; the degree of judgement and decision-making that he had to do was still, although very important, concerning a relatively small area. He was thankful that in the modern box they did not expect or require the signalman to occupy a large part of his effort in physically moving things around, and because of the inbuilt degree of safeguard and automation provided, he was free mentally to spend a bigger proportion of his time in trying to make the best operating judgements and decisions in relation to the prevailing situation, enabling him, they hoped, to give the best end product. And he would have thought this was a very necessary, very vital and a very real step forward. He did not see that the function of the signalman had changed merely because the type of box had been changed. This was an argument which Mr. Tyler and he had pursued on a number of occasions, and it continued.

With regard to automatic release of route, frankly he did not know. This was a new one to him. It had not come up in his time at B.R.B. Superficially—and he used the word as a first judgement—he could not see anything against it but he would like to know a good deal more about why they did apparently oppose it. As the point has been raised, he would make it his business to look into it.

He agreed with Mr. Tyler about trying to see if they could reach some agreed basic rules of the game in regard to the size of power box areas. This was going to become an increasing issue and he thought they ought to try, collectively perhaps, at least to set down the parameters under which they should work.

There was a lot to be said in relation to artificial lighting, from what Mr. Tyler had to say, but the point he had made in his paper was much more applicable to the natural lighting situation, which in his experience had caused much the greater difficulty.

With regard to high speed, one thing was quite clear—if they only had a small number of very high speed trains superimposed on the sort of general speed bands existing now, then they were in for very real problems and it might mean a lot of things had to be done.

Mr. L. Lloyd said that when his brother officers on the Operating Committee learned from him that he had spent an hour listening to their Chairman, and had not quarelled with anything he had had to say, they would be dumbfounded. He added that it was a pleasure to find himself in such a position. A lot, quite rightly, had been said, mostly by operators, about cost and reliability. And one could understand the constant pursuit of cost reduction. But it had also been said that the operator had not, as yet, found an effective way of quantifying and expressing in monetary terms many of the real and known benefits of power signalling, as Col. McMullen had indicated. It was also true that operators had either been unable or had not taken the trouble to express in monetary terms the cost of *unreliability* and he wondered whether operators were culpable in creating some of the unreliability that they had got by their, perhaps, over-enthusiastic pursuit of cost-cutting. There was a price to be paid. One normally got what one paid for. He wondered whether some of the things they were getting at the moment, which they found unsatisfactory, were the result of their own pursuance of cost-cutting.

Mr. Howes said this seemed to be a night for wearing hair shirts! Cost of unreliability, and were operators guilty of committing their engineers, in effect, to a cheap and nasty product? He did not know. All he knew was that if they had been, then they were culplabe. Because, if they were not careful, they were going to equate the need to minimise cost and maximise savings so as to establish financial justification; with acceptance of an unsatisfactory product they were putting what would still be a very large expenditure at substantial risk and possibly would obtain little of the operating benefits. He would not go along with that. He did not know whether it might have happened in individual cases. He could only say that he hoped it would not. He would rather personally cut his cloth in another way—cut it, if they liked, in the scope of the scheme, so that at least in what they did build and spend a large amount of money on they were still getting a reliable tool.

Mr. A. W. Damon said he would lik to thank Mr. Howes for coming, as h[e]

called it, "into the lion's den". He had come not intending to say anything, but he had been stirred a little by a remark that Mr. Reynolds made. Perhaps he had misunderstood, but he understood him to say that some 10%-15% of the delays every day were attributable to signalling failures. If he was wrong, he apologised. He did know a Region—the one he was associated with—which carried a fair amount of traffic and was divided into three divisions. One could find this sort of signalling failure quite often. Three-and-a-half failures attributable to his department, one-and-a-half to another particular department—let's be fair, they blamed them for obstructions in points; they were not his department's and they could often happen outside a signal box by a station where nobody did anything about it—perhaps it wasn't safe. Their own chap could have some miles to go before he found it. Now he had accounted for $3\frac{1}{2}$, and for one-and-a-half; he wanted to get to nine per division per day—a crude average. So he had got four to find. They were non-attributable—an expression they were all familiar with, and his audience would be surprised at some of the popular causes of "non-attributable" failures! Some of them were due to misuse of equipment.

Mr. Howes replied that Mr. Damon was carrying on a traditional argument that had now existed for the last generation between operators and not only signal engineers, but all technical departments. What he could never understand, as a poor operator, was why the technical departments did not sometimes—they always felt they were blamed quite unnecessarily—put the issue to the test. If they could have a day when they had no engine failures or signal failures, and no broken rails, and the whole of any delay that arose was purely the result of the inefficiencies of the operator, then they would really have proved the point one way or the other. Being more serious for a moment, he was sure that there were errors of omission and commission on both sides.

Mr. R. C. Hider recalled that the comment of his Traffic Assistant on the title of the paper was "Too late now!" But he was sure he would not think that tomorrow when he gave it to him to read. He wished to make a comment on the size of the area to be controlled. And he would like, at least, to invite signal engineers, if not Mr. Howes, to think about the problem from, perhaps, two angles. First of all, let it be admitted that as operators they were judged on what they did when things went wrong. And it was when things went wrong that modern signalling made it jolly difficult for them to do anything well. It usually became a matter of waiting until the signal engineer or somebody else could do something well.

The foregoing was just one side of it. Another problem was the permanent way engineer. His experience on London Transport was that it was becoming extremely difficult for him to meet the P.W. engineer's requirements unless he gave him a complete possession all day. Or else he came so far into the morning that he could not build up his a.m. peak service. But so it was. He was just saying, "Please, signal engineers, will you not forget that we operators are judged on how we do when things are not going well and it isn't always the signal engineer who doesn't go well". Neither was it always other engineers who did not go well. There were so many other people; even operators did not go well sometimes. He did not know until this evening that they carried the bag to put the stone in the points but his Signal Engineer and he both knew who carried the silver paper (the potential track circuit failure) —and it was not the operator.

Then there was the problem of the size of the panel arising from the size of the area controlled. Considering first the signalman or regulator, the fact of the matter was that in most modern signalling installations he really enjoyed a fairly regular and easy level of activity which at any moment, without any warning, could suddenly become very intense. This was not an easy proposition to accept unless one was going to help him out by putting another man in. If one put the other man in, where did he come from, how did one keep him in training and so on?

He came now to another aspect of the other problem. Someone had mentioned —and Mr. Howes had made a reference to it—the arrangements of the various equipments in the signal box or regulating

room. The medicos were, like their passengers, usually a nuisance. He hoped there were none at the meeting. But they could not afford to neglect the advice of either, and his experience was that the doctors, if they were going to be sensible, could be jolly helpful.They had been extremely helpful in saying how information should be displayed, at what height they should put their diagram, how they should light it, and how far away from the indicator or indications or signal diagram the operator should sit. And London Transport had got a unit down from Oxford to give a little bit of advice on the problem of arranging equipment for a man to see or to use.

Mr. Howes agreed that greater use should be made of specialist services and he thought it was only in the recent past that they had really started to use properly the skills of their medical officers. But he always got a bit worried with some of these things. It was so easy sometimes to translate this into not using various skills to help one make the general judgements, but rather to abrogate one's own responsibility to somebody else. This was a thing one had to watch.

Mr. V. H. Smith remarked that in his paper Mr. Howes said he trailed his coat, therefore he (Mr. Smith) would stick his neck out and take up the challenge. The paper said "signalling is expensive by any standards". The author did not define these standards but left it at that. What standards did he use to come to this conclusion? Mr. Smith had pondered on this for a little while and then reached for the information about the Victoria Line. He took the total cost—and civil engineering for the Victoria Line represented 51% of the cost, the signalling 4%, and it must be borne in mind this was signalling for automatic trains. The stations—and this was the architects' work on the station, the finishings and so on, not lighting, communications or anything like that—were 8%, twice as expensive as the signalling. The rolling stock cost 11%, nearly three times the signalling. The signalling, providing the safety, was an insurance for that very valuable rolling stock. The escalators cost 4%, just the same as the signalling. He would say to the author, "you can't afford not to have the signalling. It's a jolly good insurance and cheap at the price". (Laughter). On another point—the practice of 4-aspect signalling—the paper said that almost certainly it would be required in relation to the short headway necessary to operate an intensive suburban service. He must quarrel with this statement as representing the organisation which, he believed, operated one of the most intense suburban services in the world; in fact, they used 2-aspect signals. And he thought this policy met the author's own requirements of the simplest possible operation. A red light meant stop, a green light meant proceed. One could not get it simpler.

Throughout his paper the author talked of costs. If he wanted this 3-aspect and 4-aspect signalling, it cost money. It cost a lot more money than 2-aspect. As an operator, the author must consider if it really needed this to work the service.

In Section 6-2 of his paper the author talked of the skilled judgement exercised by signalmen in relation to situations created by train delays, out-of-course running, etc. The speaker had grave doubts about the skilled judgment of signalmen. A signalman was faced with making the decision at a time an incident occurred, at a time of stress. He made a decision and was never able to examine whether what he did was the right thing. He thought with automation it was possible to provide programmes in advance, to deal with emergencies as and when they arose. And these programmes could be created by imagining the fault that would arise—say a road blocked by a faulty train—and one could come to a conclusion as an exercise as to what was the best thing to do to keep traffic moving. Having arrived at that, one could make the programme and, with proper automating facilities, switch it in as required and let it deal with the situation.

Another factor which he had thought about quite a bit was Mr. Howes' conclusion of wanting 3 seconds reaction time for a driver. They had been shown some pictures which were very interesting, but just consider this driver and, to quote the paper, "he has to sight the signal, he wants identification, verification, interpretation and decision translated into action". That train driver, even at 150 mile/h, was in charge of a vehicle proceed-

ing along a guided path. It was predetermined for him, he had no option, the train could only go ahead. He knew the road because the Operating Department insisted that the driver knew the road. He was expecting to see a signal ahead so he knew it was coming up. And then, when it came up, it could only tell him to do one of two things, either proceed as he was going—in other words do nothing—or secondly slow down and stop the train.

Now this same driver in this day and age, when he had finished his shift after his 200-mile run which had been quoted—150 mile/h was only going to take him an hour and a half or thereabouts—when he'd finished his shift, he clocked off, tore across his depot, jumped into his Rover 2000 and drove home! Now he was in charge of a vehicle, possibly not doing 150 mile/h because there were things that prevented that, but nevertheless, he now had to guide this vehicle; he had got to watch the road absolutely. He could not take his eyes off for a second. All at the meeting were drivers, he was sure, and knew what happened if they did take their eyes off the road. The car came off the road! The driver had got to take decisions which necessitated either braking the car or altering its direction, or taking other avoiding action. Now, the Highway Code said reaction time was two-thirds of a second. At that point he would rest his case.

Mr. Howes thought that when Mr. Smith spoke about four aspects and drew a parallel between London Transport and the main line railways, he was begging so many issues as to render the comparison almost meaningless. Not least because he was comparing a system where in general they had constant speed of trains with one with high variability of train speeds even in the intensive local passenger situation. They were not all of a constant kind and they were not all local passenger trains. There were other trains intermixed. When Mr. Smith talked about the skill of the signalmen, he (Mr. Howes) was quite certain in his mind and would repeat again, that in his judgement there was a great deal of skill. It was a different sort of skill to the skills of, for instance, the signalling technician, but it was just too glib and too easy to say "well, you've provided him with a panel and all he has to do is push buttons and everything is done for him". The fact was that in the complex junction areas, with choice of routes open to him, in relation to the current situation of the trains, and bearing in mind that he had an inbuilt system of advance information on the running of trains on which he could make advance judgements as to his orders of precedence and priorities, yes—he thought there was a tremendous degree of skill and what pleased him about modern signalling was that the signalman was being freed to exercise the skills which he thought were the right ones for him to exercise, not having to bash levers about, not having to tear himself to pieces physically, but to do a proper job of efficiently controlling trains. This was why he made the point also in his talk that a great deal of thought must be given to the future relationship between the power box and the control rooms.

Again, with regard to Mr. Smith's comments about reaction time, he was not going to say that three seconds was sacrosanct. This was a group which had medical advice and opinion to go upon. All the group tried to do was to put forward an objective view—and he put it no higher because they said in the report that a great deal more research was required. It suggested that *prima facie* it looked as though in the broad order of things it was reasonably safe to say that conventional signalling was all right up to 125 mile/h. but they were not so happy about saying it was suitable beyond. But Mr. Smith's analogy between the driver driving 200 miles in an hour-and-a-half and then stepping into his 2-litre Rover begged more questions than it attempted to answer.

Mr. H. H. Ogilvy said Mr. Howes had been very candid. He admitted to having made one mistake in his career. He (Mr. Ogilvy) predicted that Mr. Howes might be on the point of making a second mistake. In Section 9 of the paper he referred to the case of moving block. He said: "I have consistently challenged the value of moving block, which, as I see it operationally, would only be practicable on open stretches of line where its value is minimal in terms of real time. For in junction areas where precedence of trains must be related to prevailing minute-to-

minute circumstances, it would have little practical value". He would like to say to Mr. Howes that in Hamburg, for example, in the new city system, there was a train control system which was working on moving block and not merely working on open stretches of line but also dealing with the particular difficulties at junctions and stations. Moving block control had been found to be essential in order to provide the very close headways needed to meet the demand for increased capacity in Hamburg. So he hoped Mr. Howes would keep an open mind on this subject for the moment. For himself he would not say that moving block would solve every problem or whether indeed it was relevant to British Railways. He had doubts about this; he would say that at the moment, it was just not proved, but was certainly capable of being made practicable. Again in Section 9, Mr. Howes said "I believe existing signalling methods are capable of being developed to meet this situation up to 125 mile/h." but he did not say how the existing signalling system, if developed, would deal with the difficulties of ensuring that high-speed trains always obeyed speed restrictions. It seemed to him that at high speeds present signalling techniques formed the weak part of any railway system. Safety was entirely in the hands of the driver, regarding recognition and compliance with the fixed and temporary speed restrictions. And he would submit that with the higher speeds envisaged in the future, if a speed restriction were disobeyed, the consequences would be much more serious than at the present time.

One final point: in his paper Mr. Howes referred to the "wiggly wire" system. He would like to take the opportunity that evening on that platform, of asking if this term could not be dropped once and for all. It was entirely misleading. He did not know who invented it, but it meant absolutely nothing—in fact for the last two years at Derby they had been very busy trying to straighten the wire out and he thought they had succeeded. (Laughter). The wiggly wire, or zig-zag conductor, had relevance only to a very small part of train control, a very particular application. And it was certainly not relevant to the main line problem.

Mr. Howes apologised to Mr. Ogilvy for offending his sense of the proper. He merely used the term because, perhaps regrettably, it was one which was, perhaps, meaningful to a lot of people who did not know a great deal about it.

As to moving block, he still remained to be convinced. This was an argument which Mr. Ogilvy and he had had in other places. When he used the phrase "practicability", he had been misunderstood. He had not meant "practical" in a technical sense, but rather in terms of its value, and probably his phraseology was rather bad here. He accepted that the capability was there—he still challenged the true value of it in real-time terms, in the British Railways situation. If they really were wanting to talk in terms of movements in terms of seconds interval, then yes, he agreed. If, however, they were talking in real terms of down to a minute or so, then frankly he would challenge its validity in their situation. But he was quite prepared to keep an entirely open mind and be convinced.

Speed restrictions up to 125 mile/h.—a fair point, but they accepted the situation today up to 100 mile/h. What the group was saying was that their broad conclusion was in fact borne out by further examination, conventional signalling in the modern sense was suitable from the driver angle up to 125 mile/h. Was the driver any more, or would he be any more inclined to disobey speed restrictions and the like than he was up to 100 mile/h? He thought this was at least questionable.

Mr. W. G. F. Thorley (visitor) said he would like to comment briefly on this most interesting paper and discussion. The author emphasised the need for strict discipline in planning and the avoidance of second, third and even fifth and sixth thoughts, and one wondered, in this era of rapid technological change, at what point in the planning process a definite halt had to be called in making amendments to the equipment to be used for a particular purpose.

The author referred to the necessity for the driver to scrutinise frequently information displayed by instruments on the instrument panel at the driving position, which involved him in lowering his gaze from the line ahead to the instrument panel. At the higher speeds, the driver rarely had time or even need to look at any other instrument than the speedo-

meter, which required, therefore, to be sited centrally and designed so that the information it gave could be read in the shortest possible time.

A previous speaker had compared the conditions attending the driving of a high-speed train with that of a motor-car; Mr. Thorley submitted that there was little comparison between the two. The kinetic energy of a train weighing, say, 500 tons, was very much greater than that of a motor car moving at the same speed and it was a fact, although difficult to quantify, that the tension under which the driver laboured increased both with weight and speed. Furthermore, the coefficient of adhesion between wheel and rail was very much less than that between rubber tyre and a macadam road surface, which resulted in the train driver being relatively more conscious of the limitations of his equipment at high speeds.

Mr. Howes replied that the point on planning discipline was something he felt very strongly about from his own personal experience over the years. What he was really trying to hit at—and that applied both to his own side of the house and, he thought, to the engineers as well, was that during the formative stage of planning it was right that there should be the toing and froing and people coming forward and saying they thought there was a better way of doing it. One got to a point where all was more or less agreed and then somebody, at some level, thought—"Ah, we've not covered this or there's a movement here, if only we could do it that way it would be very helpful"; or the signal engineer said "Well, I think there's perhaps a better way of controlling that movement". How many people in the room had seen the time when, indeed, they had actually held up and delayed the carrying out of schemes and increased the cost, and very often, because of the final rush to get the thing through, they had made a botch of odd parts of it? He did think there was a real need for all of them, of all departments, to decide that there must come a time when one cut off—obviously if it was something vital that somebody had overlooked, one could not afford to leave it out. But if it was what he called the "nit-picking" type of modification, and so much of it often was, then firm rejection should be the order of the day. This was what he was really driving at—not the sensible, necessary alteration, but the sort of silly things that could do a lot to hold up completion of planning, and indeed hold up physical work and, moreover increase cost.

The President then closed the discussion and brought the meeting to an end with a vote of thanks to Mr. Howes.

Provincial Meeting of the Institution of Railway Signal Engineers

held at

Glasgow

Wednesday, January 22nd, 1969

The President (MR. B. REYNOLDS) in the chair

Mr. D. M. Howes (British Railways Board) read his paper on "The Operating Requirement of Modern Signalling".

DISCUSSION

Mr. C. Birch, who was invited by the President to open the discussion, said that Mr. Howes had stressed the problem which was arising now and would become even more real in the future as a consequence of the increasing disparity in the speed of trains. He therefore posed the question whether the Technical Officers and the Operating Officers were giving thought to the possibility of five-aspect signalling in order to meet this particular problem of the increasing width of the speed band?

Mr. Howes replied that Mr. Birch had certainly bowled a fast ball. Five-aspect signalling? He had never consciously sat down and thought through the need for an increase in the number of aspects. Although there were some obvious merits and some equally obvious difficulties, he thought all they could do so far was to suggest it might be very worth while to take a piece of known difficult track, and by carrying out a simulation exercise, evaluate what they would get out of a fifth aspect and the likely order of increased cost.

Mr. B. Henstock said he had a lot in common with what Mr. Howes had said in his paper and thanked him very much for it. There was one point over which he was a little at variance with Mr. Howes and that was the question of the expense of signalling equipment. They knew it cost quite a lot of money but it was there for the safe working of the traffic and he thought this could not be over stressed. They must have safety and a lot of benefits were attained by resignalling.

Probably one of the best cases was that of Glasgow Central where they closed the St. Enoch Station and diverted traffic from there, and did so with the electrics giving an increased service; and what was more, they did away with four lines of rail because the bridge over the Clyde was due for renewal, and he understood from the Chief Civil Engineer that this bridge was to cost something like £750,000 to replace, plus all the annual maintenance costs thereafter. Now resignalling, and two-way working on the lines (which he did not hear Mr. Howes mention in his paper) made possible the traffic flow into and out of Glasgow Central. He thought that point should be stressed as an achievement of modern signalling.

Mr. Howes also mentioned the use of remote control. He would like to say that on the North of the River they used to have 56 signal boxes and after resignalling

that number was reduced by 50%. When they resignalled the South Side, from Glasgow to Wemyss Bay and Gourock, they had one new signal box at Paisley, a modernised one at Gourock and a new panel in Glasgow Central Box, so that the extent of control was very much increased. The proposed resignalling of the Glasgow to Carlisle line would allow probably for a new box at Motherwell—the only signal box. He thought this remote control would be worth while and reliable, and he thought the reliability of the equipment must be stressed as well.

Later on, Mr. Howes had mentioned remote control and the increased speeds. Did he think they would get to cab signalling without lineside signals, and possibly to driverless trains?

Mr. Howes agreed with Mr. Henstock that they must not get costs out of proportion. What he was really trying to stress was that in the world in which they lived—like it or not—they only got what they could financially justify. Signalling was costly by any standards and he did not think anyone would disagree that they must never stop trying to find ways of reducing costs, provided that in so doing they did not impinge on safety or vitiate operating benefits that they more than offset any limited cost saving. What he had been trying to stress was the essential need for a joint approach. It was not a job for the operator or signal engineer in isolation: each side must go on trying to make a contribution to finding ways of reducing costs.

On remote control, he thought Mr. Henstock had underlined his point. He was sure remote control was a must. It had been, he thought, most valuable and highly successful, considering that at the time of its introduction it was something entirely new. All he was pleading for was that having now got it established and eliminated the earlier bugs, the need was to develop the equipment, and he believed there were proposals in hand towards the possibility of obtaining such a degree of integrity that, in the event of a small failure at an isolated part of the total complex, operating action could be confined to that rather than having to treat the whole complex as suspect as was necessary today, thereby introducing most cumbersome and time consuming arrangements throughout the failure period.

As to the future, he had been associated with the track-to-train communication study throughout and it now seemed clear that the system was technically on, although this had to be put to the test under service conditions. Whether financially it was going to be at a price which they could afford might prove to be a much more debatable point. A great deal more work needed to be done before conclusions could be formed. Certainly they would have for the present to install conventional modern signalling, but he thought track-to-train communication in its ultimate form, with overall speed control of trains and the possibility of getting rid of fixed signals, would prove a "must" for future high-speed running, certainly above 125 m.p.h.

In regard to the driverless train, it would seem that technically this would prove a practical proposition, but he thought they would have an incredibly difficult task, which in his judgment would take many years to resolve, in trying to convince the public that it was safe to be running at a high speed with no one at the front end, and certainly in trying to convince the Trade Unions, so his answer was that whilst the proposition might be technically feasible, they were so far away from the practical application that it should not consciously affect their immediate judgment.

In regard to two-way working, this was obviously a very good thing if used in the right circumstances and over the right section of line. Its obvious use was in relation to platform lines at the major passenger stations. In France the principle had been used extensively in terms, for instance, of making do with three tracks instead of four, one of the tracks being signalled for two-way working. The essence of the French case was that there was a major preponderance of train flow one way in the morning and in the reverse direction in the evening.

One application of two-way working on which he felt a great deal more research was required, was to see if there was a possibility of devising a simple method of putting in two-way working during periods when single-line working was necessary. With mechanised track maintenance the demand for weekday possessions had very substantially increased, and a serious

limiting factor in the granting of weekday possessions was the loss of line capacity which arose with conventional single line working.

Mr. D. Binnie recalled that Mr. Howes had spent a period of his time in the Scottish Region. With regard to operating participation and making known the operating requirement, he would say that on the Scottish Region they had been trying to do this for about 20 years. They had put operators into the signalling camp for months and had put signalling almost into the Operating camp. He did not think they could complain about lack of Operating appreciation even on the Signal Engineering side on the Scottish Region and for that reason they were very happy with the schemes they had. But the Operating outlook, as Mr. Howes said, must be faced up to in a more realistic fashion and he would like to concentrate on something which might be parochial to their own Region. He felt that they were at the turning point in signalling. Mr. Birch had mentioned the need for five-aspect. He was now questioning the need for four. Had they not gone to the extreme in four? Could they not get back to three? When they put in four-aspect it was on the conventional braking system, when they had to stretch out for the high-speed trains, whereas now they were turning to new braking systems—air brakes, disc brakes, etc. They were almost back to the point that the high-speed train could brake in a shorter distance than the low-speed conventional train. This was their problem on the Scottish Region.

They were about to enter the high speed area; at the moment their maximum speed in Scotland is 75 m.p.h. So they were talking on something dear to their hearts—going up to 100 mile/h and over. He thought when the operator stated his requirement he meant traction as well, and he felt it was vitally important to bring down the cost idea and to do it in relation to the efficiency as well as the safety.

Mr. Binnie concluded by repeating his earlier question: "Four aspect, or back to three?"

Mr. Howes in his reply recalled saying when he mentioned the number of aspects that this was a very controversial step, as could be seen by the fact that two gentlemen had raised the issue that night. All he could say was that they must not be fixed in their attitude, and that if circumstances changed they must not be afraid of changing what might have been a cherished view. Mr. Binnie was quite right in that a claim was made, although it had not yet been put to the test, that with the Advanced Passenger Train they would have a braking system enabling them to work at very much higher speeds with their present braking distances, and thus avoid the necessity for resignalling. The proof of the pudding would be in the eating, but if one assumed that the claim proved successful, he agreed this might well change their attitude and thinking, in the longer term, towards the number of aspects they needed. Therefore he would like to leave the matter at the point of stressing that they must not be entrenched in their attitudes, for what might be right at this moment might not be so in the future. They must therefore keep an open and flexible mind and judge the issue on the circumstances as they emerged, although it is likely to remain an area where there would continue to be a good deal of difference of opinion—all strongly held and vociferously argued.

Mr. W. Dean, remarking that this was the first time the Institution had really had a specification of signalling requirements by an Operating colleague, and the paper would no doubt serve as a general operating specification on signalling requirements.

He had been very impressed with the film shown, particularly the third section simulating train speeds of the order of 120 mile/h, and felt that under these conditions there was a great strain on the driver, even on the relatively short journey shown, which was possibly exaggerated by the apparent regular and rapid movement of the overhead traction structures. Nevertheless, on a long journey he felt that there would be a great strain on footplate men at such speeds, and in his opinion speeds of something a little less than 120 mile/h were the limit they could go to with orthodox signalling, without additional aids in some form of automatic train control.

Reference was made in the paper to the need for planning, strict discipline in planning, and avoidance of second, third

and even subsequent thoughts on a project. He would wholeheartedly support the author on this point and was sure a lot of his colleagues will support this too. There was nothing more costly, delaying or frustrating than having to cope with modifications and changes when one got down to implementing a scheme.

In several instances in the paper the author quite rightly referred to the cost of signalling, and whilst it was admitted that this must be kept to the minimum, he would like to point out that signalling costs in a comprehensive scheme did give a good return and were comparable with other expenditure. If one took the recent experiences in the Glasgow/Gourock electrification scheme, the percentage of the signalling costs to the whole scheme was not unreasonable in relation to civil and electrical engineering costs; in fact it was less than a third, and it must not be forgotten that signalling was providing the maximum movement facilities to give earning power and formed a very effective safeguard for expensive rolling stock; and not least, it offered protection to the passengers carried, which was their business.

In their recent experiences in calculating costs for subsidies of unremunerative passenger services, it had been shown beyond doubt that the cost of signalling was one of the lowest factors. Nevertheless, he did agree that this matter of cost must be kept in the forefront in all their deliberations on new schemes.

In this respect, he felt that a most useful contribution in this direction could be made on the Operating side if some formula could be arrived at to evaluate the unseen advantages gained on the Movements side in introducing a modern colour-light signalling scheme.

He would like to make one brief point about headway, and would suggest that this should be specified as x minutes for a certain class of train, and the headway for the rest would automatically follow. In looking for a suburban scheme it was the headway for stopping trains that must be catered for primarily. In this connection it was assumed that the remarks on headway were based on trains running on green aspects, but there was a certain merit in considering the headway on suburban schemes based on the double-yellow aspect, notwithstanding Mr. Binnie's remarks on the possibility of 3-aspect signalling in general.

As regards train describers, although this was an important part of a modern signalling scheme, he felt that they had in some cases paid a very high cost for this part of the signalling system.

Finally Mr. Dean endorsed the author's comments on signalling arrangements for low-density branch lines and felt that they should direct stronger efforts to simplifying signalling for single-line branches carrying passenger traffic. Indeed, if this had been done in the past he felt that some of the branch lines now closed could have been retained as economic concerns.

Mr. Howes, replaying to Mr. Dean, explained that the film they had seen was, in fact, an edited version of the full film, which ran for rather longer. A point he had not made during his talk was that the part of the film which simulated a speed of 147 m.p.h. produced, on those originally involved in making it, the effect after about two minutes, of screwing up their eyes. They came to the conclusion that with the normal track noise, plus a quite noticeable lineside flicker, coupled with the maintenance of a constant forward lookout, at this sort of speed the degree of concentration required by the driver would be excessive. However, the film was made to serve the immediate purpose of forming a general impression about the effect on drivers at a very high speed, and they might be interested to know that he had made a suggestion to the Research Department that the locomotive simulator that was designed for drivers on the London Midland Region in the new a.c. locomotives should be brought back into use to enable a series of controlled tests to be carried out, so that they might obtain a much clearer idea of the driver implications at very high speeds. The simulator could operate at any speed they wished; the driver could be put through a series of manœuvres; and they could obtain, from a cross-section of drivers, not only how they reacted, but their own impressions. However, they still thought that conventional modern signalling would probably be satisfactory at speeds up to 125 mile/h but not above this figure.

On signalling costs, he did not think either Mr. Dean or Mr. Henstock really disagreed with what he had to say. They

would recall his making the point that signalling modernisation had on the whole been very much a success story, but the blunt fact remained that costs could prove a serious barrier to the speed of progress in regard to any further new signalling installations. They must not become defensive on this issue, but regard it as a challenge to both departments to find further ways of minimising costs and maximising benefits. Capital was very difficult to obtain and nobody was going to agree to an expenditure of many millions of pounds unless it could be shown to be a really worth-while proposition.

Mr. A. B. Allison said he had been very interested in the point that it was thought that in their new modern concept they could place their signalmen remote from the track—indeed, perhaps underground. He could see no difficulty in doing this because, in Scotland for instance, at the moment they spent something like two-thirds of their day in darkness, and thinking of his visit to the London Transport Control Room for the new Victoria Line, and acknowledging that the L.T. service was not as complicated as their own, nevertheless the Control Room was not associated with the railway at all. It was quite a distance away and he could see that in the future they might lose their Controls as such, and that with fewer signalboxes, the regulation would be carried out in the box.

In looking at the film, he thought there must be some relation between the spacing of the structures and the speed because he quite clearly had the sensation that at 116 mile/h and even at 147 mile/h, when going from multiple-track to two-track, the visual interference from structures seemed to be less. It might be that this was just a personal view. Had this journey been done at night when there was no interference from structures? This, indeed, might give some further tie-up between the mental process and the reaction of the drivers.

Mr. Howes replied to Mr. Allison's last point that the answer was "no". This was the only film they had. The exercise was carried out in as much depth as possible and with the help of as many experts in the field of human behaviour as they could assemble. He repeated that he thought the next logical step was really to test out driver reaction by using the locomotive simulator to which he had referred, and which was similar to an aircraft simulator used for the training of pilots. Use of the simulator provided all the normal sensations of motion and sound, any speed can be chosen, and, as far as the driver was concerned, it was identical with driving the train, as the film at which the driver was looking was a specific length of track and the normal observance of signals, etc., applied. Tests could be fully controlled and the views of medical and other experts could be obtained to reach firm conclusions. They must bear in mind that they were likely to be moving into higher speeds, possibly up to 125 m.p.h., before, in any event, they could get help from the track-to-train communication system, and therefore urgent answers to driver reaction to high speeds were very necessary.

Mr. R. G. Bates was very interested in the size of signalbox areas and noticed that an exercise was carried out on the L.M. Region in connection with the Weaver Junction-Carlisle route. He understood it was proposed that three signalboxes be provided, and not one, as evidently was considered. Now why three? Why not two or four? It was also stated that the provision of three signalboxes would be cheaper than one signalbox, but if he understood correctly the decision had already been taken that three signalboxes was the correct solution. What then was the limiting factor in size? Was it the controller's mental capacity to "see" the whole picture? And, if this was so, how many movements could be controlled, in, say, one hour?

Returning to the thorny question of cost, signal engineers were being disturbed and what had rankled over the years was that it had been said signalling cost too much. He noticed that Mr. Howes said signalling was costly. There was a vast difference between these two statements.

Mr. Howes agreed entirely with Mr. Bates' final comment. He said that when he heard people use phrases like "it costs too much" it always seemed to him that they were made without much thought—almost a subconscious reaction of a person who felt superficially that the price was very high and it really ought not

to cost so much. The fair answer was that they got only what they asked for. If at times items were included for which they had not asked, this again was probably their own fault for not having spelt out sufficiently clearly their requirement, or allowing the signal engineer to get away with the inclusion of something without challenge. His plea was simply that there should be a continuing attack to try and minimise the costs in any way they could devise.

In regard to the size of power box areas, he could give a specific formula which would make a nice, neat package, but he thought there were certain guidelines, so far as he was concerned, although his colleagues would not necessarily agree with him. He had already touched on some of them. He believed there was a limit to the number of panel operators that could be effectively co-ordinated by one controller. Secondly, they were moving increasingly from the Divisional Control Room into the power box. Again, he saw no joy whatever in lumping into a single power box, merely because it was technically feasible, sections of line which had neither physical nor geographical connection one with the other.

Finally, he had indicated that from a number of exercises they had been able to show quite conclusively that two or three boxes in place of a single box were often financially more attractive. Incidentally, the illustration he gave about three boxes in place of one was worked out before any decision was reached as to the correct course of action.

Mr. R. H. Parker returned to the question of two-way working. It seemed to him that with the Reed system they now had scope to provide two-way working at a somewhat lower cost than had been possible in the past, provided that the headway in the "wrong" direction was not expected to be the same as in the "right" direction.

There were two slight complications however. One was that the operators found it very difficult to produce figures for savings in the staff required. The other was the question of spring catch points, which were a perpetual bogey not only to them but also to the civil engineer so far as his maintenance was concerned. Did Mr. Howes think there was any scope in the future for getting two-way working if it would pay for itself, once they were rid of catch points?

Mr. Howes replied that they had been attempting over the past year to obtain some relaxation from the Ministry in relation to catch points in new signalling schemes. To cut a very long story short, the problems were such that without carrying out a massive series of tests, they really had no case that they could sensibly make at this point in time. They had devised one or two ways in which they could limit the number of catch points and the Ministry had indicated that they were prepared to look at each case on its merits. The problem, of course, was the unfitted and partially-fitted train, and he certainly thought that when the time came to see the last unbraked vehicle leave their system, both they and the Ministry could begin to think quite differently. At the present time safety considerations made any substantial relaxation impracticable.

The other issue to which Mr. Parker made reference was one of which he knew very little at the present time and he was waiting for his Signalling colleagues at the Board to tell them more about it. If among other things it opened up the possibility of a cheap form of two-way working, even with the application of catch points and with an improved headway compared with one-direction movement under existing circumstances, then certainly they must have a look at it and evaluate the potential value in relation to costs.

Mr. O. S. Nock (Senior Vice-President) said it had been a great pleasure to him to attend the meeting; it was always extremely interesting to see the way the discussion of a paper went in different places. In London, for example, there had been a good deal of discussion about signal aspects; also on line capacity and power box design. In fact at least one London Transport member could not understand Mr. Howes' claim that four-aspect signalling was necessary for running a very intense commuter service. They claimed to run a far more intensive service with two-aspect signals than British Railways had ever heard of. Of course, that was easy enough for them because all their trains ran at the same speed. They all had exactly the same accelerating and

braking power, and in such circumstances signalling might almost be called a boy's job compared with what British Railways had to do.

The more one travelled abroad, the more one realised the terriffic problems under which British Railways were working, with the tremendous spread of the speed band from, as Mr. Howes said, the 35 mile/h loose-coupled freight to the 100 mile/h plus passenger train. It was easy enough on a line like the Lötschberg in Switzerland which they travelled over on their summer convention two years ago. There they had locomotives of great power and all trains could run at exactly the same maximum speed; and not only that, but they ran at the same speed uphill as downhill. So they could work a single-line service over steep gradients with remarkably short headways. They achieved a terrific line capacity in that way, whereas elsewhere, as Mr. Howes emphasised, line capacity had to be related to the spread, or the variation in traffic.

He knew one railway abroad on which the line capacity had been worked out in relation to gradients and running lines. Having worked it out theoretically, they reduced it; they multiplied it by 0.6 in order to get down to reality, to cover all the idiosyncracies of working a single line station by the station staff concerned. In other words, they could work it out on paper very carefully, but they did not reckon to get more than 60% of that capacity. That was the correction factor they worked with.

The other thing was the question of arranging the power box so that the signalmen could see the trains. They had seen a case in Switzerland where a very modern and quite sophisticated C.T.C. job was working a complete single-line railway. It was true that the box was not put underground, but it was put on the other side of the town. It was about 10 minutes walk to the signal box, or rather to the control panel, from the nearest bit of permanent way to which the signalling related. He did not know whether he personally would go for putting boxes underground, although the lighting problem presented to signalling contractors in getting good visibility of the panel indications made one very much inclined towards the smallest of windows. The Scottish Region's box at Glasgow was one of the contractor's major headaches in this respect.

In conclusion Mr. Nock thanked Mr. Howes once again for an extraordinarily fascinating paper that had drawn big audiences both in London and Glasgow. It was such a very live topic, and he felt the Institution owed Mr. Howes a great debt of gratitude.

Mr. Reynolds commented that Mr. Howes had mentioned the simulator several times, and Mr. Nock knew of an experience with this machine which he hoped he could persuade him to relate.

Mr. Nock said he went all the way with what Mr. Howes said about the simulator. He had the privilege of seeing it in action when they were training the drivers, when it was installed at Willesden, and a remarkable incident took place at that time. The drivers were told what class of train they were working, because a driver who was working a partially-fitted train had to use different braking techniques to a man who was running a fully-fitted freight or an express passenger. In this particular case the driver, whether wittingly or unwittingly, was given the wrong classification of the train; he thought he was driving a train fully-fitted with vacuum brake, whereas in fact the simulator was set for him to be working a partially-fitted freight. He was driving along quite leisurely, the signals were coming up at him, and it was all extremely realistic until he got, first, a double yellow, then a single yellow and finally a red. Because he did not use the appropriate technique he overshot the red. The experience was so realistic that when he "stopped" he put down the window and looked out of the simulator to see by how much he'd overshot!

The President, in summing up the discussion, drew attention to two points. One had just been mentioned by Mr. Howes, and he felt himself that with the automation of signal boxes and the taking of minor decisions out of the signalman's hands in greater degree, so the decisions left to the signalman grew gradually more and more important.

Secondly, unlike the popular conception that all operators liked to retain every possible facility in a resignalling, Mr. Howes was advocating on the grounds of cost that before any modernisation scheme was produced, serious thought should be given to what facilities could be dispensed with. That was a very welcome thought coming from an operator!

The meeting closed with a vote of thanks to Mr. Howes and to the organisers of the occasion.