Technical Meeting of the Institution

held at

St. Enoch Hotel, Glasgow

Thursday, February 26th, 1959

Mr. L. J. M. KNOTTS in the chair

On the meeting being declared open, Mr. Knotts said:—

I welcome having the opportunity of being in the chair tonight and I wish to keep the preliminaries as short as possible but I feel it is convenient to present certain matters for your consideration.

This is the first provincial meeting of the Institution of Railway Signal Engineers in Scotland for some considerable time, and I think we would welcome them at more frequent intervals. It is gratifying to see a good meeting of members tonight and we welcome the visitors.

We are particularly fortunate in having Mr. D. G. Shipp, Vice-President of the Institution, and we thank him for coming from London to be with us. He has very much the Institution's interests at heart and I am going to ask him to kindly say a few words after I am finished and before the Paper commences.

After this I shall have pleasure in calling upon Mr. Foster to give us his paper on "Relay Remote Control Systems." I am quite sure we shall be listening to his paper with considerable interest.

There will no doubt be those who will wish to join in a discussion afterwards and Mr. Foster has kindly consented to answer questions on the paper.

I will now ask Mr. Shipp, as President Elect of the Institution to speak to us.

Mr. Shipp

Mr. Knotts has kindly said that I have very much the interests of the Institution at heart and of course it is also true that the Institution itself has very much at heart the interests of those members who cannot travel regularly to London to attend its meetings.

I cannot recall when the last meeting in Glasgow was held, but the Council always keeps in mind the members in provincial areas and would like to help them as much as possible.

We feel that we can help you best if you first help yourselves by forming a local section, such as we have seen established already at York and Bristol.

The way to set about forming a Local Section is first of all to get more of your members to join the Institution, because the present number in Glasgow, which I believe is about 20, is really not sufficient. I feel this number could be augmented, particularly by getting more Technician Members, so as to bring your strength to say between 40 and 50 members, which is usually considered appropriate before a section should be formed.

Once a section has been formed in this way, the Institution can help by offering Technical Papers and Authors to read them and it can help further by making a monetary grant to help in the running expenses of the section. The annual subscription for Technician Membership is £1 1s. 0d., and this entitles the member to advance copies of all papers read in London, in addition to enabling him to purchase the Institution Journal at half the price.

Mr. Knotts has been good enough to tell me that he will arrange for a supply of application forms to be held by his Area Assistants and I hope there will be a good response, so that you will be in a position to apply to the Institution for a section to be formed in Glasgow.

I would also like to mention that the Institution is pleased that British Railways have recently agreed to make a lump sum grant of £30 to any member of the staff in receipt of a salary up to and including the maximum of P. & T. Group "A" (or Class 1 Supervisor) who is successful in passing the Institution's examination.

In conclusion, I should like to say how much pleasure it gives me to be here in Glasgow to attend this meeting.

The Chairman called upon Mr. G. I. Foster to read his paper.

Following the reading of the paper, a short film on the working of C.T.C. on the New York Central Railway was shown, and Mr. Shipp showed three slides on Electronic Remote Control which is the system in operation on the Styal Line.

Relay Remote Control Systems

By G. I. FOSTER (Graduate)

On railways signalled in the British tradition we expect to find many small signal boxes, each one an interlocking on its own with manual block control between each box. On single lines further apparatus such as electric train staff is necessary. Numerous boxes make the co-ordination of traffic somewhat difficult and it is expensive to maintain staff at all signalboxes at all times. It is sometimes technically difficult to arrange for the temporary closing of boxes and even if this can be arranged a considerable reduction in line capacity results. Particular difficulty arises in switching out boxes on single lines.

At some junctions and termini, power schemes concentrate larger areas under the control of one signalbox and permit an economy in staff, even taking into account the increased number of maintenance staff that may be called for. However these schemes are usually justified more on the grounds of efficient traffic working than direct financial economy. The cost of cables places a limitation on the size of the area controlled from one signalbox under a conventional signalling system. As the area gets larger and the average distance of apparatus from the box increases, the cable cost rapidly rises and becomes prohibitive.

It will be realised that the individual signalman has a very limited picture of the traffic situation in his area. A more general picture is obtained by the control centre which receives telephone messages reporting the passage of trains and the controller is able in an emergency to arrange, by instructions to signalmen, diversions of trains from their normal paths. The situation as seen by the controller is never a very up-to-date one however, since the boxes reporting the passage of trains may be situated at considerable distances apart. It would appear from the traffic operation point of view that the controller should ideally be able to survey an overall picture of the traffic situation and give instructions direct to the drivers of the trains concerned. This is the ideal which remote control seeks to serve, although in particular instances the controller may be dealing with a smaller area than is usual for a conventional control district.

Modern technical developments make possible the setting up of routes and the clearing of signals by remote control by one operator where previously this could not be justified economically Thus all traffic moving over a wide area can come within the control of one man situated at a central point.

The following situations appear to be particularly favourable for the application of remote control.

1 Control of single lines with the elimina- of signalboxes at passing places. This eliminates the problem, which sometimes arises on a single line, of opening all boxes for the passage of only one train. However, the application of remote control to such a line may be difficult to justify economically if the staff available at the passing places are required for other purposes. Such a situation may arise where the passing loops are all situated at stations and the stations are staffed by porter-signalmen whose presence is in any case required for commercial reasons. The removal of signalling duties from such personnel cannot, of course, alone justify the cost of remote control equipment.

It should be realised that to supply remote control to any single line or, for that matter, to any main line, it is necessary to equip the signalling system with power equipment and with continuous track circuiting to enable automatic control of the block to be effected.

2 Conversion of double track to single track with consequent saving when remote control is employed. In this case the saving to the Civil Engineer by the eliminating of the second track may more than offset the additional cost to the Signal Engineer of the remote control equipment.

3 Control of single or multiple satellite interlockings surrounding one large interlocking. In this way the range of control from one large interlocking is extended beyond that which would be otherwise economically possible. We may consider a simple triangular layout with a station at the apex where the main signalbox would be situated. The other two points of the triangle, which may be a mile or more away, would have small interlockings which could be more economically operated by relay remote control than by either maintaining manned boxes, or by controlling their equipment by direct signalling circuits in cable.

As is well known actual cases of remote controlled interlockings have already been brought into use, operated by electronic means, on the Styal line between Manchester and Crewe, and additional satellite interlockings are planned, controlled from main interlockings at London Road, Wilmslow and Sandbach.

4 Major schemes involving whole divisions, as envisaged on the New York Central where four tracks are to be converted to two, with both way working on both tracks and remote control of the entire system. Certain main line systems, where alternate lengths of four track and of double track exist, are suitable for consideration. Remote control would obviously be ideal for ensuring the best possible use of this layout, particularly with both-way working on the double track.

Relay remote control systems have seen most service in the U.S.A. and they have been developed there to a high degree of reliability. The name Centralised Traffic Control is generally adopted in that country, often abbreviated to C.T.C.

The problem presenting itself to the American Signal Engineer has generally been rather different from that described for British conditions. Train Despatcher and train order operation has been in general use, and this has inevitably led to much wasted train time where train crews are required to operate points at intermediate loops to shunt their train for another to pass. Manned interlockings are generally confined to major intersections and manual block working is the exception. Under these circumstances great saving in train running times, as well as increased line capacity, help to justify expenditure upon the C.T.C. equipment. Considerable extensions in the application of relay systems of remote control were made during World War II when much increased capacity was required on the many single track main lines.

Continuous track circuiting and automatic permissive block working were already widely in use in the U.S.A., and it was a comparatively straightforward matter to adapt this to operation by centralised traffic control. There has also been considerable use of centralised traffic control to reduce double track main line to single. Instances have occurred where power operation of points has not been used, but where a signal is used instead instructing the train crew to operate the points by hand. Such a situation however does not seem to lend itself to British conditions.

Remote control systems must convey controls from the central office to the signalling apparatus and receive back indications from the signalling apparatus over the minimum number of line wires. The equipment provides only a " long arm " operating a relay which is equivalent to the local signalman operating the switch on the local relay interlocking panel or attempting to pull a lever in a frame. All the interlocking circuits are provided locally in the conventional manner and all the safety side of the signalling system is inherent in them. If the remote control conveys an instruction which the local interlocking cannot permit, then the instruction is ineffective. Because of this, absolute " fail safe " circuits are not necessary for the remote control and the use of intermittent coding on one or two pairs of line wires is permissible. Most systems are based on this principle.

Coded remote control may be either electronic or electro-mechanical, i.e. a relay system. The relay systems employ a coded d.c. transmission and have the advantage of using well tried-relays, and circuits with a known and proved reliability. Any maintenance and inspection will be facilitated, since the apparatus is fundamentally similar to the relays and circuits with which railway linemen are familiar, and any relay system lends itself to fault-finding by the visual inspection of relay operation. This maintenance facility may be most important where remote control equipment is installed in outlying areas with difficult access and where the staff is difficult to obtain.

The first system to be described is that known as the G.R.S. Type H Centralised Traffic Control System, which is most suitable for controlling a number of stations all situated in line. The second system is suitable for the control of a number of field satellite

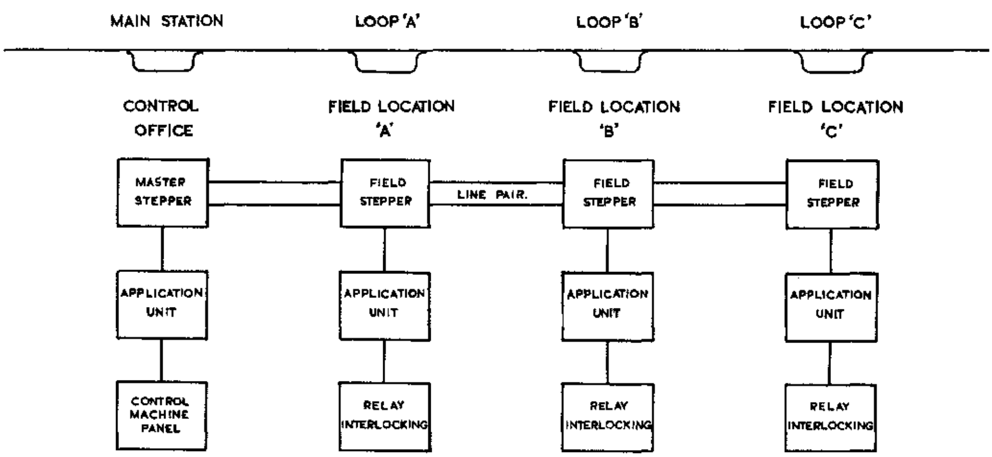

Fig. 1 Block Diagram of C.T.C. System

interlocking surrounding a main interlocking and is known under the trade name of " Syncrostep."

Centralised Traffic Control System Type H

Fig. 1 illustrates a typical layout for a Centralised Traffic Control System. The line comprises say 80 miles of single track main line with passing loops every five miles. A control office is situated at one end of the line and field locations at the intermediate loops.

The " control office " sends out groups of impulses (one group forming a code) to field locations in order to control apparatus there. The control office receives groups of impulses to indicate the state of apparatus in the field.

" Field locations " are each associated with local relay interlockings at the loops and these field locations receive groups of impulses and respond to them to operate the apparatus at the location. Groups of impulses are transmitted back to the office to indicate the state of apparatus at the location.

At the control office a control machine is provided for the operator consisting of a master stepper unit and one or more application units. Normally, but not necessarily, one application unit is associated with each field location on the system.

Each field location consists of a stepper unit and an application unit as well as the local relay interlocking.

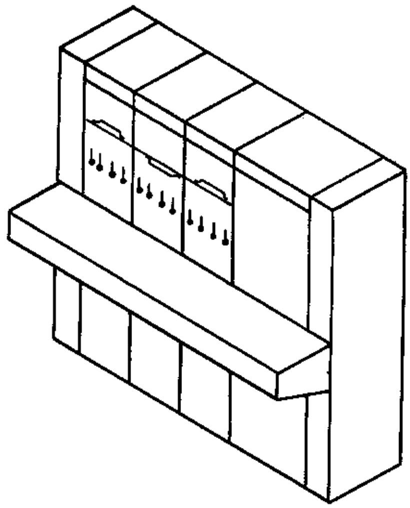

Fig. 2 Sectional Construction of Control Machine

Stepper units provided at each field location are identical. Application units at each field location vary according to the apparatus to be controlled or indicated at the location concerned.

At the control office a control machine is provided for the operator and this contains all the relays associated with the office end of the system. The control machine is divided into sections, each of

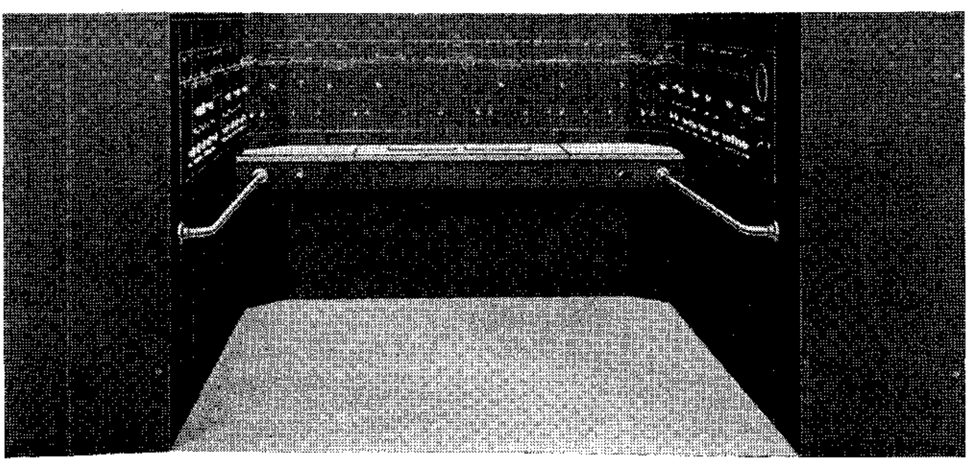

Fig. 3 Typical C.T.C. Control Machine

which has a small relay cabinet associated with it. Each section corresponds to one or more field locations and a front panel contains the various switches necessary to control the apparatus and the indication lights necessary to display the state of apparatus in the field. The steelwork of the machine is also divided into sections corresponding to the panel sections and it is possible to build the machine up as if it were a box of bricks. If necessary it is possible to add further sections after installation. Fig. 2 illustrates the method of building up the sections of the control machines. Fig. 3 is a photograph of a typical installation. Fig. 4 shows a typical panel section of the control machine in detail and fig. 5 shows the withdrawable relay cabinets.

A separate section at the end of the machine contains the relay cabinet for the master stepper. A panel section associated with this contains various special switches and a screen covering a bell and buzzer used to give audible indications. Facilities for testing and for the control of the power supplies are provided in an end section of the machine. This will be described later in greater detail.

The control office and the field locations are connected by one pair of lines either in cable or on an open pole line. At the master stepper and at each field stepper a special polar line relay is provided to follow the line current. The groups of impulses forming the control or indication codes are transmitted by this line and only one group of impulses can be transmitted at one time. However, the groups of impulses last only a few seconds, and this is not a disadvantage for the type of line on which this system is employed.

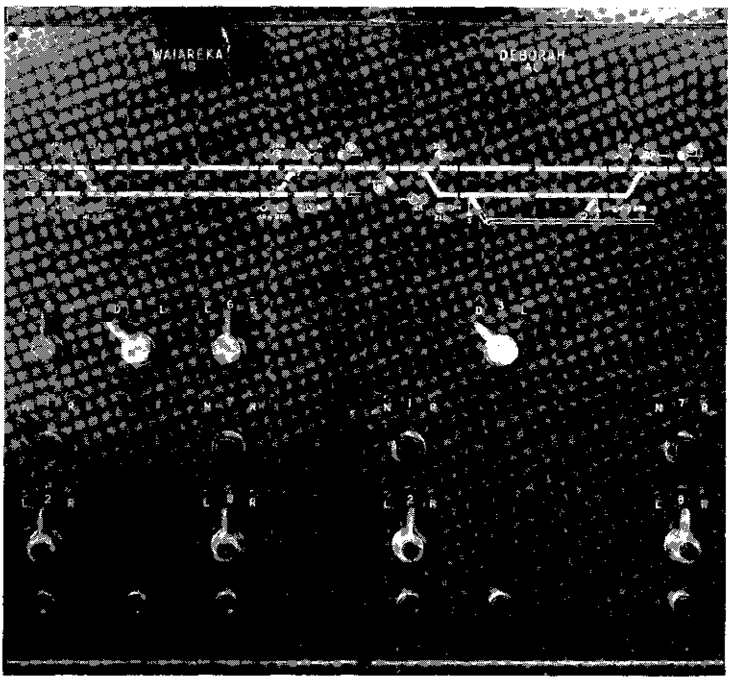

Fig. 4 Control Panel Section

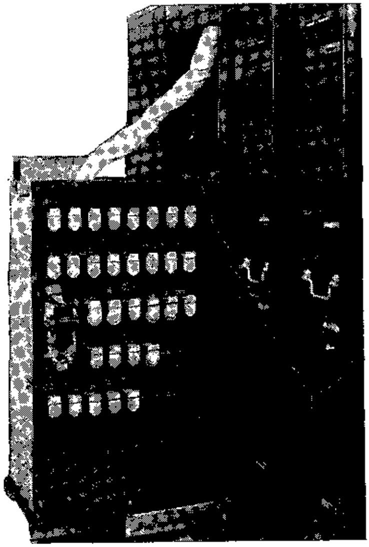

Fig. 5 Withdrawable Relay Cabinet

A " control code " is the group of impulses sent from the office to a field location and a " control cycle " is the term used to describe the complete sequence of relay operations necessary to transmit this " control code." An " indication code " is the group of impulses sent from the field location to the office and an " indication cycle " is the complete sequence of relay operations associated with it.

Description of Step-by-Step Operation

Imagine two ten-position switches, one situated at the control office A and one at the field location B and connected as shown in fig. 6. Associated with each position of the switch at A is a 2-way function switch which connects either positive or negative to the line AB. Associated with each position of the switch at B is a relay which, operating on the magnetic stick principle, is energised either positive or negative according to the polarity of the current received along the line AB and which will then stick in the last operated position when energy is removed.

If the ten function switches at A are first positioned and then the two 10-way switches at A and B are moved in unison through the 10 steps, it will be seen that the 10 mag-

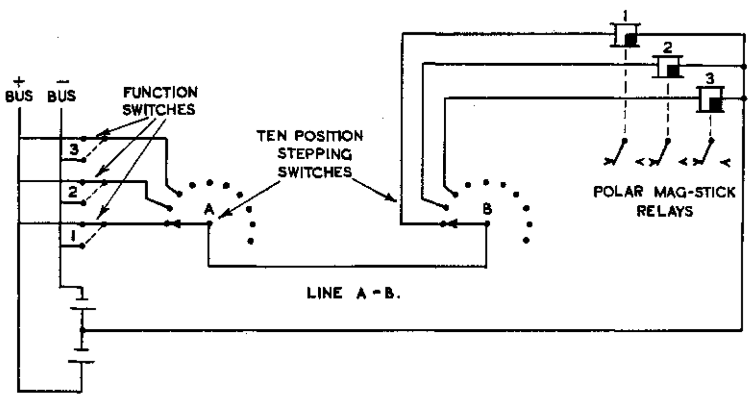

Fig. 6 Simplified Stepping Circuit

netic stick relays at B will finish in the positions corresponding to the function switches at A. In this way control of 10 functions has been transmitted from A to B along a single line pair. This is the basic principle on which control codes are transmitted by the centralised traffic control system.

Form of Code used

The codes used on 2-wire systems of centralised traffic control may be either of the time or polarity type. With the polarity system one line is either positive or negative with respect to the other line and this polarity may be changed up to 10 times during the cycle. With the time system the length of each impulse can be either long or short. On the system being described the control and indication codes both consist of 10 impulses. In the case of control codes these impulses are of polarity type. For indication codes they are of the time type, both long and short "on" and "off" periods being used.

Description of Relay Stepping

It is, of course, not possible to use multi-position switches working in unison at the

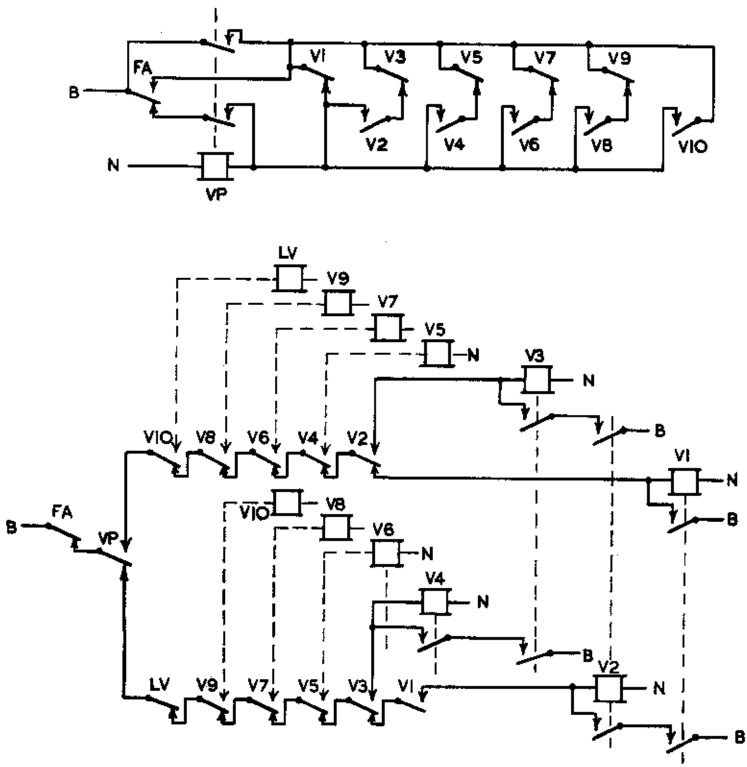

Fig. 7 Relay Stepping Circuit

office and field location as described in the brief introduction. Instead, relays are used to count the steps using the circuit shown in fig. 7 to achieve the same object as the switches. Ten relays are employed to count the 10 steps and these are numbered V1 to V10. A half-step relay called VP is also necessary. The line relay F which follows the polarity of the line directly operates a repeater FA. At the start we consider all relays normally de-energised. During the first " on " period with FA picked up, VP is energised over FA up and V1 down. VP completes a stick circuit over VI back. At the end of the first impulse we get the first " off " period. V1 will pick up over the backs of the even numbered V relays and over VP up. It will be seen that VP remains held over a stick circuit over the FA down and VP up.

In the second " on " period which now follows, FA picks up and it will be seen that there is no holding circuit for VP which is therefore released. V1 remains held over its own stick circuit. During the second " off " period it will be seen that V2 is picked up over VP down and the back contacts of odd V relays from V3 and a front of V1 relay. V2 also then completes its own stick circuit.

During the third " on " period VP again picks up over FA up, the back contact of V3 and the front contact of V2. VP will similarly pick up during each odd numbered " on " period. During the third " off " period the circuit is completed to pick up the V3 relay over VP up and FA down and back contacts of higher numbered even V relays. Similarly during subsequent odd " off " periods.

During the fourth " on " period VP releases and will do so during subsequent even " on " periods. During the fourth " off " period V4 is picked up and subsequent even numbered V relays will be picked up during even " off " periods. During the final "off" period, which is actually the eleventh, a final relay LV is picked up.

In this way both the office and the field location are enabled to count the steps and keep their steppers in synchronism. The same stepping circuits are used for both controls and indications.

Operation of a Control Code

The switches on the appropriate application section panel are turned to the position desired, e.g. the switch for No. 1 points may be turned to the reverse position. This sets up the polarity of this particular step of the control code. The start button below the switches is now pressed, and the code is transferred to the master unit.

The line is normally energised in the negative sense. All the stepping relays in the office circuit and field location circuit are normally de-energised. The master stepper commences the control cycle by causing a break in the line current and following this by a prolonged positive control step. During this positive step, known as the " Conditioning Period," various relays at both the office and at all field locations pick up to initiate a control cycle. The first " off " period now follows, during which relays V1 pick up at all steppers.

The control code proper follows commencing with the first " on " period. The first group of steps are used to identify the location which is being called. The number of steps used depends upon the number of field locations involved, but a probable number would be six. The polarity of each " on " step is decided by the appropriate station calling relay or the switch position on the panel. The polarity is transferred to the line, by two relays which switch the polarity of the line current.

All field locations are provided with polar sensitive line relays, the coils of all line relays being connected in series by the line. At the commencement of the cycle all steppers follow the code. Each field stepper however is provided with a circuit which causes it to retire if the steps of the call sign portion of the control code do not correspond with its own call sign.

Half of the total field locations will be allocated a positive step for the first step of the call sign and half of the field steppers will be allocated a negative step. If the step transmitted is a negative, then all field stations set to receive a positive on that step of the code will retire. Similarly on the second and subsequent steps. Thus half of the field location steppers retire on each step of the call sign. On the last step of the call sign we are left with only one field stepper still stepping. This is the field location being called. The remaining steps of the control code are used to position the apparatus at the field locations and their polarity is determined by the position of the switches of the control panel. As the steps are received by the field stepper their polarity is determined by the field line relay and they are counted by the V relays. When these steps are received their polarity is recorded by the picking up of PS or NS relays which remain held in the energised position until the end of the cycle. For example, if the eighth step is negative then relay 8NS is picked up and held up.

After the last " on " period a prolonged " off " period follows called the clear-out. During this clear-out period the last stepping relay LV picks up and providing all steppers have counted correctly, the code stored by the PS and NS relays is transferred to the application relays. During the remainder of the clear-out period all stepper relays return to the de-energised position and the system is restored to normal. After completion of the clear-out the office restores the line to its normal negative state.

The application relays are either of the neutral type with stick circuits or are of the magnetic-stick type and once energised, they remain in this position until a cancelling reverse current is applied. These application relays correspond to the control switches of a normal relay interlocking and they will in turn operate the normal signalling circuits.

Operation of an Indication Cycle

Since the indication code consists of a time code, both " on " and " off " periods can be varied to give long or short intervals. This gives an effective 20-steps for a 10-impulse code and is most valuable, since it enables more indications to be sent back to the office than controls received. Under most circumstances this is a situation which is desirable, since there are nearly always indications to be sent back which are not associated with controls, for example track circuits.

Like the control code, the indication code is divided into two parts. The first part comprises the call sign of the field location calling and the second part describes the position of the apparatus being indicated. If six effective steps are necessary for the call sign then 13 steps will be available to indicate the position of apparatus.

Each piece of apparatus will have associated with it a relay such as the track relay, point detection relay or signal control relay, which has to be indicated back to the control office. To detect a change in the position of one of these relays, which will necessitate an indication code being transmitted, a special quick release called the CH relay is used. This CH relay has a stick circuit over both back and front contacts on each of the relays to be indicated. When any of these relays changes over, CH relay is released during the transit time and remains down until the indication cycle is completed, when it again picks up ready to detect the next change.

Provided the line is free, the field stepper commences the indication cycle by picking up a relay which locks out all field steppers further out along the line from the office.

This is done by both breaking the line and switching out the line to locations beyond the field location which is calling. The office detects the line break and itself removes energy from the line, ensuring that all field locations between itself and the location which is calling are also forced to follow the cycle and cannot themselves proceed to initiate an indication while the first indication is being delivered. Following the line break the office connects negative to the line for a conditioning period during which the various relays associated with the start of the indication cycle are picked up at the master stepper and at all the field steppers out to the field stepper which is calling.

The field stepper now determines the remainder of the code by opening and closing the line. Accurately timed slow release relays are used to determine the length of the long " on " and " off " periods. The short " on " and " off " periods are determined by the normal quick acting relays in the stepper circuit. Code connections are set up to determine whether the slow release relay is introduced into a particular step or not for the call sign part of the code, and the position of the signalling relays to be repeated determine whether it is introduced for the remainder.

At the office the indication code is received by the line relay and counted in the the same way as for a control cycle. The length of the particular step is determined by whether a slow release relay does or does not release. This relay is shunted by a resistance and the value of the resistance is designed to make slight alterations to this timing possible. For the call sign part of the code the length of the step determines whether a registration relay associated with that particular step does or does not pick up. The last step of the call sign must always be long and this picks up a registration relay called RX. The picking up of RX transfers the information received on the registration relays, by picking up the particular station relay concerned. One station relay is associated with each field stepper which can call the office. Should the indication code not be correctly received and RX not pick up, then no station relay would pick up, and the cycle would be ineffective.

The remaining steps of the incoming indication cycle are transferred at the application unit associated with the station relay and according to whether the step concerned is long or short, the application relay associated with that particular indication will either be picked up or dropped away. These application relays are normally of the magnetic-stick type and remain in the last operated position. The application relays in turn control the indication lights displayed on the panel. At the end of the indication cycle a long clear-out period is enforced by the office after which all relays return to their normal state.

Capacity of the System

The basic 10-step system enables a choice to be made between the number of stations to be controlled and the number of controls to be effected at each station. Table 1 gives details. It will be seen that if there are only 16 control stations then six controls can be effected at each station whereas if there are 64 control stations then only four controls can be effected at each station. It will be noted also that whereas 16 control stations enable six controls to be effected at each station, 15 indications can be given on the same number of indication stations. It is possible to shorten the indication cycle if necessary should the number of indications permitted be greater than the number of indications required.

The time taken to transmit control and indication cycles also enforces a limitation on the capacity of the system. In order to avoid congestion it is important that the total number of control and indication cycles transmitted during a given period of say 8 hours should not exceed more than 60% of the total time available. This is important since only one indication or control cycle can be transmitted at one and the same time. Cycles are awarded different priorities and it is important that the cycles with the least priority, probably indications from the furthest field station, receive a chance of being transmitted and the indications received at the control office, within a reasonable time of the event happening. With this system a control cycle takes approximately 4 seconds and an indication cycle from 5—7 seconds. If the total cycle time does not

Table 1

Alternative Capacities of Type H C.T.C. System

Controls		Indications	
No. of Stations	Controls per Station	No. of Stations	Indications per Station
1	10	1	19
2	9	2	18
4	8	4	17
8	7	8	16
16	6	16	15
32	5	32	14
64	4	64	13

exceed 60% of the time available, every indication should be displayed within one minute of the event happening.

Allocation of Priorities

The operator is free to set up and start control cycles at any time. If the line is busy these control cycles will be stored and sent out at the first opportunity, which will occur immediately following the completion of all control codes already stored, or of any incoming indication cycle then being received. Control codes will always take priority over any further incoming indication cycles which have been set up but not yet transmitted. Control cycles stored will normally be sent in the order of the control panel sections of the control machine, starting from the master stepper end.

If indication cycles are started simultaneously, then the field stepper nearest to the office normally takes priority. Provision is made to ensure that once one field location has transmitted an indication, it does not yet get an opportunity to send any

Fig. 8 Power and Test Panel

further indication cycle until all other field locations which have indications stored have had their chance.

Provision is made for the operator, should he wish to do so, to cancel all control cycles which may have been stored but which have not actually started to go out. A key is provided for this purpose on the master panel.

Other Special Provisions

A special code can be transmitted to any field location upon the operation of a switch and the pressing of the start button for that location. This operates a special code which is sent to the field location and is arranged to operate a bell or other device to call the lineman.

Provision is made for a special code to be sent to any field location which will cause that location to send back an indication code describing all indications. This may be used when the operator is doubtful as to the accuracy of the indications displayed on his control machines.

Fig. 8 shows the power and test panel which is provided at the end of the machine. Special indication lights are provided in order that the lineman may see the polarity of the line circuit at any time. A line ammeter is provided, and also a voltmeter for recording the local battery voltage. A special switch enables an outgoing control cycle to be stepped slowly instead of at the normal rate. This makes it very easy for the lineman to follow the position of all the relays concerned during stepping, and so locate faults. A rheostat is provided to vary the line current. Another rheostat is adjusted to the value of the normal resistance of the line, and a switch provided so that the master stepper can be switched to it for test purposes.

In field locations provision is made for switching the line through, and then isolating that particular field stepper from the line for test purposes Provision is also made to terminate the line at the location. This is called sectionalising the line, and is done by connecting a parallel circuit across the line at this location through a resistance equivalent to the remainder of the line beyond the location. Since the whole line is connected in series a break at any point puts the system out of action. By sectionalising the line at the location nearest to the break, the line becomes closed again and the controller is able to operate up to the location at which the line has been sectionalised. Provision is also made for the line break to be detected by the master stepper and an audible warning given. If desired equipment can be provided so that the line can be sectionalised automatically at the location preceding the break. An indication is given on the control panel to show at which location the sectionalising equipment has operated.

If the line condition is such that the codes become liable to distortion, a D.C. code repeater is included at an intermediate location and this regenerates the code. Basically it is another master stepper keyed by the incoming distorted code.

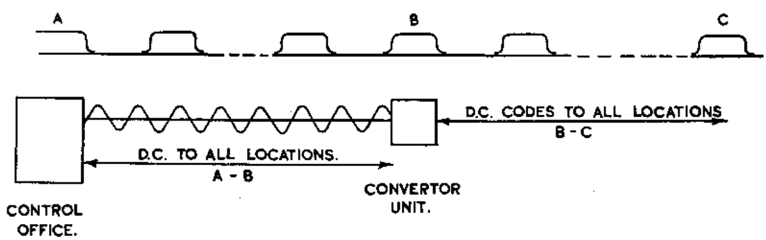

Fig. 9 C.T.C. Carrier Sections

Power Supplies

A 24-volt battery supply is required at the office and at each field location. The standing current is only about 1.5 amps. but rises to approximately 6 amps. during the cycle.

A separate battery is provided for the line and the voltage for this supply will vary with line resistance. A limit of 200 volts is however normally imposed. The line current will nominally be 70 ma., the current at the office end being governed mainly by line leakage. It is important that the normal line current at the furthest location should be a minimum of 60 ma.

Application of Carrier to Relay Remote Control

Should the lines being operated exceed the capacity of the basic relay remote control system described, the line can be divided into two or more sections and the sections furthest removed from the control office can be operated over the same line using a.c. carrier frequencies with a converter at the end of the carrier section to change back to D.C. Fig. 9 illustrates the scheme by a block diagram.

Since this is a polarity code system, it is necessary to employ two different carrier frequencies for the outgoing control code, one representing positive and one negative, and also one carrier frequency for the incoming indication code. It is usual to provide electronic equipment in duplicate so that should a failure occur, a simple switch-over can restore operation after which the faulty equipment can be removed for servicing.

For each additional carrier section an additional master stepper is required at the control machine, since we are now operating several sections of relay remote control simultaneously, although only using the one line pair.

Superimposed Telephone Circuit

It is possible with this equipment to operate a local telephone circuit superimposed

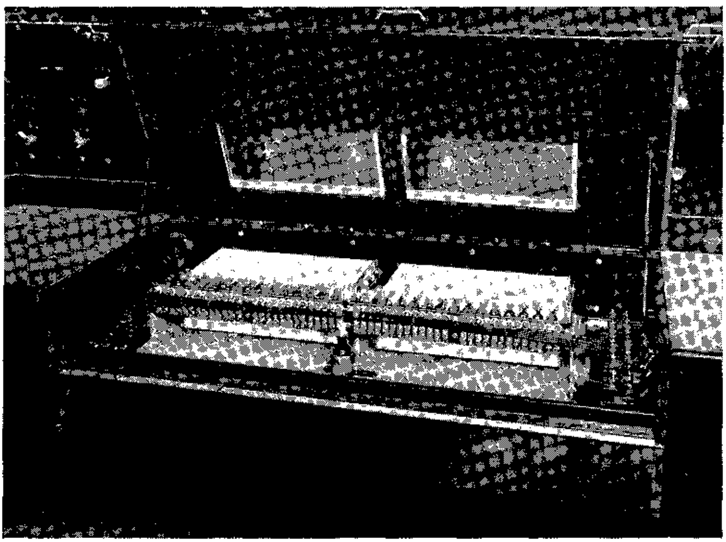

Fig. 10 Train Graph Recorder

on the d.c. remote control lines, although good reception is difficult due to the d.c. switching on the line, and the use of superimposed telephones except as an emergency service is not recommended.

Train Graph Recorder

To enable a record to be kept of all train movements and also to assist the operator in identifying the various trains in his area a train graph recorder is provided. Fig. 10 illustrates such a recorder.

Indications are received from the track circuits at the entrance and exit of the passing loops in the normal way. When these are received at the control office they not only illuminate the usual track lights on the panel, but also operate one pen of a multi-pen moving chart recorder. The chart is divided on a time scale in one direction, and in the other is divided into passing loop sections. When the pen is operated, a mark is made against the appropriate passing loop, and the operator has only to join up the marks to complete a train graph.

Interchangeability of Apparatus

The system is arranged so that all field steppers are identical, except for the external connections setting up their call sign, and the complete stepper units are usually provided with plug couplers so that a spare field stepper could be taken out to a field location which was giving trouble, and the faulty field stepper replaced in a matter of minutes. Similarly the master stepper is also fitted with a plug coupler and a spare unit may be held ready at the control office. The relays used in this system are of a small robust tractive armature pattern and are individually plugged in. They are larger than post-office relays, and have a reliability equivalent to ordinary signalling relays. They have silver-to-silver contacts with high contact pressures, and have been operated on life test for several hundred million operations before needing servicing. The normal servicing period of the equipment is expected to be about two years, or two million cycles in the case of very heavily used systems.

The system of Centralised Traffic Control just described is by no means the only possible system suitable for a similar layout. Other systems employ line relays connected in parallel across the line instead of in series. Yet other systems employ a time code for both control and indication and other systems again employ three or more line wires.

Syncrostep System

The Syncrostep system is designed to control one field station only from a main interlocking or control office. If several remote interlockings are to be controlled from one central interlocking then each field location is connected by a separate line-pair to its own office stepper. The system is designed to give quicker operation than the normal C.T.C. system and since each field location has a separate line, simultaneous control of several stations or simultaneous indication from several stations can take place.

The line circuit contains normally energised line relays at both the office and the field location. The line current is normally uni-directional on this system.

The control code usually consists of seven steps, although a larger system has 11 steps. During each step energy is either applied or not applied to the line by the office. The field line relay is thus either energised or released during each step. The steps are defined in time by the free swinging of an oscillator at both the office and the field location. The oscillators are released almost simultaneuosly at the commencement of the cycle and they are accurately timed so that for the $3\frac{1}{2}$ or $5\frac{1}{2}$ swings necessary to define seven or 11 steps they do not appreciably go out of synchronism.

To achieve economy and to speed up the stepping, normally energised counting (V) relays are employed on this system. During the first half swing the relay V1 releases. During the second half swing the relay V2 releases. During the third half swing relay V3 releases relay V1 picks up again. During the fourth half swing relay V4 releases and relay V2 picks up again. During the fifth half swing relay V1 releases a second time and relay V3 picks up. During the sixth half swing relay V2 releases and during the last half swing relay V3 releases. In this way a different combination of the V relays is achieved for each step. Advantage has been taken of the fact that the relays release quicker than they pick up and by using several of them twice over, only four relays instead of seven are needed.

Operation of a Control Cycle

In the description of this system the steps during which energy is supplied to the line are known as marks and those during which energy is not applied to the line are known as spaces. During a control cycle the first step is always a mark and is used to lock-out any incoming indication. The next five steps supply the actual code and the last step is used for a parity check to ensure the integrity of the code sent. Either a mark or a space is assigned to this last step to make the total number of marks in the last six steps an odd number.

A separate code is allocated to each control to be sent from the office to this particular field location. A control panel is provided with switches in the usual manner and the positioning of these switches determines whether a connection is made for a mark (M) or a space (S). Start buttons may be provided along with the switch in the same manner as with the C.T.C. system already described, or alternatively, the control may be sent automatically on the turning of a switch. The major portion of the control cycle is determined by the permanent jumper connections made over contacts of a relay associated with the particular control which has been initiated. At least one step however will be determined by the actual position of the switch and the parity step will also be determined by the position of the switch to make the total number of marks odd as has previously been mentioned. For examples, a particular switch controlling a pair of points into the reverse position might determine the fourth digit and call for a code MSMMM SS. If the points were to go normal, the code might then be MSMSMSM.

It is usual to employ start buttons with switches controlling signals so that these can be returned to the normal position without transmitting an unnecessary control code, since the signal in the field will in fact have been returned to danger by the overlap track circuit.

The mechanical oscillators are normally held latched by an electro-magnetic structure. On the initiation of a control cycle the line is opened at the office and the line relays released. The office oscillator is also released and starts to swing. The releasing of the field line relay unlatches the field oscillator. This first " off " period is known as the " Conditioning Period."

The contacts normally made when the oscillator is latched are known as the " A " contacts. As the oscillator swings through centre another set of contacts known as the " B " contacts are made, and as the oscillations continue " A " and " B " contacts are made alternately.

When the " B " contacts at both field and office are made for the first time the relay V1 releases at both places. When the " A " contacts are again made, relay V2 releases. In subsequent steps an MS relay associated with each step is either picked up if a mark is sent or not picked up if a space is sent.

These MS relays remain up for the remainder of the cycle and at the conclusion of the cycle a decoding circuit over front and back contacts of these relays is arranged to pick up the appropriate application relay. The execution circuit which carries out this operation will only be completed if the final MS relay is in the correct position for the correct parity step. This checks the receipt of a complete code. At the completion of the seventh half-swing the oscillator is again latched in the " A " position and a clear-out period follows. The system is then ready to repeat a further control cycle or to receive an indication.

Operation of an Indication Cycle

An indication cycle is essentially similar to a control cycle but is of course sent from the field to the office. The cycle normally starts with a space instead of a mark. Since it is usually necessary to send in several indications at one and the same time it is usual to double the number of steps for indications by using the oscillator twice over. Thus having oscillated for $3\frac{1}{2}$ cycles, the oscillator is again latched up and released for a further $3\frac{1}{2}$ cycles. A 7-step system then has 14 steps for transmission of indications. Changes of the signalling relays in the field which have to be transmitted are detected by a CH relay in the same manner as for the relay remote control system previously described. No location call sign is of course required, since only one location is connected to the system. The marks and spaces received in the office are recorded by two relays, the " odd " mark relay and the " even " mark relay. If an odd mark is received this is executed direct to the application relay in the following even period and similarly an even mark received is executed in the following odd period.

This is known as the progressive delivery of an indication code.

Capacity of the System.

Since with the 7-step system five steps are actually available to describe each control, it will easily be seen that the total number of controls which may be sent is 2^5, i.e. 32 controls. If seven steps are used twice for indications, this enables us to send 13 indications simultaneously. Similarly an 11-step system would enable us to send 512 controls and receive back 21 indications simultaneously. The number of indications to be transmitted can of course be increased if these are arranged in groups and appropriate station relays provided at the office; only one group of indications will then be transmitted at any one time.

Cycle Time of the System

With the normal rate of stepping the system will transmit a control in 1.3 seconds and receive an indication in just over twice this time. It is possible however to increase the rate of oscillations and to reduce the overall time to about one second.

Power Supplies

Both the field and office steppers require a 28-volt power supply. This must be reasonably stable. The standing load for the 7-step system is normally about 1 amp. at the office and 1.25 amps. at the field. The line is supplied from the same 28-volt battery and a current of around 40 ma. would be normal.

General Conclusion

For all normal requirements relay remote control systems are available which fulfil all the requisite conditions and have a reliability equivalent to that of all other signalling apparatus used by the railways. Although the time of operation may be somewhat longer than for electronic systems it is considered that they do in fact give times which are consistent with maximum operating efficiency, under the conditions of the lines on which they are operated. This has been proved by many years of experience in the United States and in many British Commonwealth Countries which use systems basically of the types described.

DISCUSSION

Mr. Knotts in opening the discussion stated that Mr. Foster had given a very interesting Paper and he had clearly indicated some of the conditions under which C.T.C. could be employed and is in fact employed, particularly in America very widely.

It is true that the conditions in different countries vary appreciably and it is particularly true of the U.S.A. and this country. Long distances without junctions and with a relatively sparse train service apply in the U.S.A.

He was very interested in the matter of speed of indication and presumed Mr. Foster would agree that whether you use relay impulses or electronic means, depends upon how much of the railway system is placed under the control of one operator at the control station.

In the U.S.A., more territory has been added where electronic scanning of the functions is adopted. This means that one operator is controlling very appreciable lengths of line and is able to do so because of the very high speed of indications received against the controls he is putting out.

There is no doubt that C.T.C. methods will come more into prominence in the railways in this country and the singling of double lines in certain localities is quite likely to be the principal application.

It would seem to him that if C.T.C. is used where we have interlockings comparatively close together with junctions, and with the frequency of traffic experienced in this country, that very high speed of indication will normally be required. He was however pleased that Mr. Foster had concentrated on the all-relay system in his Paper and he thought he had been quite right to do so as it facilitated appreciation of the problems.

Could Mr. Foster give some indication of the traffic frequency on the main single line of 80 miles referred to on p. 94, and also state whether the figures quoted by him regarding the number of operations of " life test " for relays, mentioned on p. 104, had been related to relays in use or in some other way.

The **Author** in reply to Mr. Knotts indicated that the line capacity could be increased by adopting the electronic system or with a relay system using multi-core cable which would provide a separate pair for each interlocking, indications being received in two seconds.

So far as the example mentioned on p. 94 is concerned, this related to a system which was to be used in Rhodesia covering slightly more than 80 miles of track, 30 boxes and passing about 20 trains per day, although the maximum capacity would be greater than this figure. So far as the figure of hundred of millions of operations for relays is concerned, these figures had been obtained in the laboratory. It was to be expected that 20,000,000 operations would be achieved in actual service without the necessity to remove the relay for servicing.

Mr. Henstock referred to the very high cost of reservicing relays of which a very large number were in use in the Relay Remote Control System and felt that the electronic system would obviate the use of a large number of relays and so reduce the cost of maintenance. He also asked whether the line wires were in open form or whether they could be in cable form and if so whether the impedance and resistance limits the distance for working such a system. So far as faults were concerned, he would like the author to say how far the system would work with:—

(*a*) A disconnection of the line wires.

(*b*) A short circuit of the line wires.

Referring to fig. 7 of the Paper, he asked whether the author could enlighten him on how the stick relay V.1 was de-energised.

The **Author** in reply to Mr. Henstock stated that while the electronic system would cut down the number of relays in use at the Master Stepper, large numbers of relays would still be required at the field stations for registering the incoming code, and the saving in cost of re-servicing would not be so very great. Referrring to the question of open wires or cable, he stated either one or the other could be used but that there was a limit to the working distance, depending on the size of the conductor but that this could be overcome by the provision of carrier circuiting. In reply to the query on the stick relay V.1 shown in fig. 7, he stated that fig. 7 was a schematic diagram and not all the controls were shown.

Mr. Dean commented on the very excellent Paper and expressed his pleasure at being able to hear a Paper being read by by a man who was so very much master of his subject.

He asked the author whether there was a limit to the size of the area which could efficiently be controlled by one man, keeping in mind the mental capacity of the man concerned. He also felt that C.T.C. was generally regarded as applying to single lines and was effective for running between large towns with fairly wide open spaces in between. In addition, he wondered whether twin or duplicate twin cable would be justified in certain circumstances. He felt that the cost due to power operation, continuous track circuiting and signalling for all movements would be high and that the system could best be applied to wayside passing loops not usually found in this country. In addition, wayside stations in this country were usually manned by the hybrid grade of Porter/Signalman and while the signalling duties could be taken away no great saving would accrue if the portering duties remained.

He would also like to know whether constant electrical point detection was provided in the local circuit.

The **Author** in reply to Mr. Dean said that he had no information on the maximum size of area which could efficiently be controlled by any one man but he was aware that the Rhodesian Railways were considering employing two men for each panel which amounted approximately to 30 stations per man and he pointed out that the men dealt mainly with through running traffic, shunting being controlled locally. So far as duplicate conductors were concerned, he felt it was a matter for the Signal Engineer to consider and justify on economic grounds. The ideal condition would be to have the lines in separate cables on each side of the line. He confirmed that constant detection was provided.

Mr. Shipp requested that further information as to how the number of controls and indications given for the Syncrostep system had been arrived at.

The **Author** explained that the controls were sent one at a time and that all steps except two were available to obtain the necessary combinations. With a seven step system, the total number of controls is thus 2^2, with an eleven step system it is 2^9.

All indications from one station on this system are normally sent together in one code and the number of steps available is one less than the steps in the code, the first step being used for lock-out. If the system is an 11-step system, then 11 steps will be used twice for an indication code, giving 22 minus 1, i.e. 21 steps for 21 indications. If the indications are divided into groups and only one group is sent in each cycle, then one step must be allocated to select the group and 20 will remain for indications in each group. Thus a total of 40 indications can be catered for. By further subdivision into groups, still more indications can be transmitted.

Owing to shortage of time, discussion on the Paper was therefore brief.