Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Wednesday, November 9th, 1960

The President (Mr. M. W. OWEN) in the chair

The minutes of the Technical Meeting held on October 20th, 1960, were read and approved.

The President introduced and welcomed to the meeting Messrs. J. Busby (Associate Member), R. O. Weaver, G. C. Gale and J. G. Deane (Students) who were present for the first time since their election to membership.

The President then introduced and welcomed Herr K. F. Kümmell (Member) from the German Federal Railways and requested him to read his paper entitled "The Development and Application of New Methods of Signal Engineering in Germany."

The Development and Application of New Methods of Signal Engineering in Germany

By DIPL.-ING. KARL FRIEDRICH KÜMMELL (Member)*

1. Historical Survey

After the first interlocking frame to be used in Germany was delivered by the English firm of Saxby in 1861, German signal engineering developed according to certain principles some of which differed in various respects from those applied in other European countries.

In Germany the setting up of routes and the operation of signals are the responsibility of one man. He receives train informations from neighbouring stations and using block apparatus releases the routes on the interlocking prior the subordinate signalmen set up fresh routes. This station controller often operates from a signalbox and himself set the signals from there.

Another feature of signalling in Germany is the intermediate connection of special route locking equipment between the points and the signals. The signalman tests with a route key to see that the positions of the points for the route of a train are correct and locks them in their correct positions. The route key itself will, after being thrown, be locked through a block instrument, which will keep it locked until the train has travelled through the section. The signal can only be set at " line clear " when this pegging operation has been completed. This additional equipment within the interlocking system is only used for through traffic. During shunting operations the points are not locked and—at least in mechanical interlockings—signals are not usually used. It is only fairly recently that these safety techniques have begun to be applied to shunting also. Because the points are

* German Federal Railway

operated freely during shunting they must be made trailable so that an engine approaching a wrongly-positioned pair of points is not derailed. The signalmen themselves operate the points for shunting movements and in this matter are completely independent of the station controller.

From 1863 onwards mechanical interlockings were constructed by a fairly large number of signal manufacturing firms according to their own designs. The most widely used forms were those manufactured by Max Jüdel in Brunswick and Schnabel and Hennig of Bruchsal. They are still fairly widely used today on the German railways. Since 1925 only one uniform type of equipment has appeared. In 1872 the firm of Siemens & Halske in Berlin began to manufacture electrical block apparatus for the section block and for the control lockings between the station controller and the interlocking frame. Block equipment of this type is to be found everywhere on the German railways and in many other countries.

In 1892 Siemens & Halske A.G. built their first electrical interlocking frame, further developed forms of which have come into increasing use since the beginning of the 20th century. The principal feature of this equipment is that the setting up of the route is checked and locked with interlocking slide bars and lockings similar to those in the mechanical interlockings. In these electro-mechanical interlockings the levers for setting the points, routes and signals are arranged in a row or—in the most recent versions—in four rows. Both mechanical and electro-mechanical interlockings continued to be manufactured up to the end of the second World War.

In the earlier type of interlocking track release equipment using insulated track sections for checking the route was used only in rare cases, so that the route had to be checked mainly by inspection of the track and the points. Because the routes had to be checked in this manner interlockings could only be used for the operation of a limited portion of any station layout. In larger stations therefore a large number of interlocking frames were required. This necessarily involved the splitting up of the operating personnel into several groups, although all the interlockings in a particular station remained under the control of one man.

The controllers in each station work independently of each other to a great extent and thus lack a general comprehensive view of the railway operations over a particular line section. Central supervisory points in the form of station controls for large stations and traffic control points for very busy sections of the line are therefore allotted the duty of constantly supervising and checking the actual progress of operations over their extensive area of control according to instructions received by telephone, and of taking the right decisions to restore operating conditions to normal as quickly as possible in cases of failure. These central supervisory points pass information to the local station controller while still allowing him to decide on the necessary measures to be taken to ensure the safety of railway operation within his area.

Because control on the German railways has developed from earlier signalling techniques it has tended to become decentralised. This is feasible as long as the time-table is strictly adhered to, but the disadvantages of the system rapidly become apparent as soon as any extensive alteration is made to the schedule, and particularly so in cases where the traffic on the lines or in the stations is especially heavy.

After the second World War the railway authorities in Germany as well as in other countries adopted the relay interlocking system which had been newly developed and which operates only with relays, so being independent of mechanical interlocking devices. This led to changes both in engineering techniques and in the system of operation.

By the simple operation and exclusive use of track release devices the work of the signalman was greatly reduced and the signal zone considerably extended. Operating supervision also tended to become increasingly centralised. This system of control is still only in its beginnings in the relatively small number of the new electrical interlockings, but it will become widespread in the course of the next few decades.

Since the old methods required the employment of a large staff, many of whom were frequently unoccupied during the many intervals between train and shunting movements, this changeover to a new method of signalling and to centralised control brought about a significant reduction in the numbers of railway personnel required, which could only have been achieved otherwise by the electrification of the lines. Safety was greatly increased and the performance of various functions of railway operation greatly speeded up. The new methods of signalling have become one of the most important means of rationalising and increasing the revenue of the German railways.

2. Geographical Interlockings

The route-relay interlockings used by the German railways possess certain features which distinguish them from types used on other railways, although since they all have very similar functions to perform their basic construction is essentially the same. The first small trial interlocking was put into operation in Dusseldorf in 1948 and the first interlockings of a mass-produced type followed in 1950. Since that time the general design of the operating equipment has changed little although the design of circuits and relays has been greatly improved and simplified. About 400 route relay interlockings were built to replace approximately 900 interlocking systems of the old type. This is only a small proportion, however, of the total of 10,500 interlocking frames used on the German railways. The effect of the introduction of route-relay interlockings on the methods of railway operation and on the rationalisation of the duties of railway personnel is so fundamental that all projects for the future are based on the use of these systems. The large majority of existing interlockings will eventually be replaced by interlockings of the geographical type, and all new interlockings are being built according to the new design.

The firm of Siemens & Halske A.G., Brunswick—and to a lesser extent that of Standard Elektrik Lorenz A.G. of Stuttgart—is engaged on the development and manufacture of these geographical interlockings, which are also known in Germany as push-button locking frames. The designs of the interlockings produced by these two firms differ in various details of the operating equipment, in their circuits and in the types of relays used.

The characteristic feature of all geographical interlockings is the use of illuminated visual track diagrams in the form of desks which show a comprehensive diagram of the station. These are composed of individual elements having the same dimensions, and which at the same time contain the push-buttons for the operating devices, all being arranged geographically. The signalman usually sits at this desk, on which he has in front of him a diagram of the station and the area under his control, and operates the routes for train and shunting movements directly from this desk. In geographical interlockings the basic element consists of a framework of 38×65 mm. (Siemens) or 35×35 mm. (Lorenz) for the lamps and buttons. The contacts for the lamps and push-buttons are mounted in rows on this support. The lamps (1.2 w., 24 v.), inside a removable cover plate, illuminate the diagram of the tracks and the points and signals. The desks are built up of these basic components to the design required. The push-buttons are only able to be moved in one direction, that is they can be depressed only, being returned to their normal position by means of a spring. Rotary and other types of switches are not used. In order to prevent accidental operation of the buttons the equipment is constructed in such a manner that two buttons must always be operated simultaneously. They should be mounted as far away from each other as possible so that they cannot be depressed with the same hand. In order to set up the routes the buttons at the beginning and end of these routes are operated. The buttons which are used in cases of emergency or failure are mounted outside the track diagram at the edge of the desk.

The large majority of the first 400 route relay interlockings are installed in small intermediate stations in which two or three of the old type of interlockings have been replaced by one route-relay interlocking frame. The railway official in charge of such equipment performs the duties of both the station controller and the signalman, which work does not occupy him full-time, and he is often free to carry out various other duties in the station, e.g. the sale of tickets, operation of level crossing barriers, etc. Even in larger stations a single geographical interlocking can replace a number of interlockings of the older type. In these cases also the signalman performs the duties of the station controller even when traffic is very heavy, so that the whole control of the railway operations becomes the responsibility of one man.

The control of railway operations is always concentrated as far as possible. Where traffic is so heavy that one man is unable to take complete control—experience has shown that the working limit is 1,200 trains and shunting movements every 24 hours—the authority must be shared.

Although during the first few years of operation using geographical interlockings a division of duties between the station controller and the signalman was preferred, the trend now is to place the responsibility for a whole area on one man so that control is concentrated, at least in the larger stations of the railways.

The co-ordination of railway activities for a very large station is accomplished by stationing the personnel operating the interlockings in one room. When the various duties are divided up the station controller is assigned a particular push-button control desk from which he transmits his instructions for the running of trains to his subordinate signalmen by means of push-buttons. The buttons can be arranged either within a track diagram or in rows on a diagram on the wall.

The German railway authorities have economised on the numbers of operating personnel required by installing the first geographical interlockings in those stations which are likely to benefit most from the centralisation of control and which have the most convenient layout. In the future, however, they intend to revise the layout of the signalling installations over fairly large sections of line.

While the basic form and mode of operation of the route-relay interlockings has remained largely the same, a great deal of progress has been made in the design of circuits and the structure and design of the relay devices. At first the basic principles of the earlier signalling systems were carried over into the geographical interlockings and long routes were used which could only be released when the train had travelled over the whole of the route. After this system had been in use for a few years a further development was made which was the change-over to short sectional routes allowing quicker route-release. This development also made the use of the interlocked shunting route possible, a feature which has since been widely used. The most recent development is the system whereby every pair of points is directly connected into the route interlockings. Thus the peculiar unit for the route, a characteristic of the German signalling system, is divided into as many parts as there are points for each route, so that now points and signals are directly connected. This means that from a technical point of view the German signalling system now conforms more closely to those used on other railways.

The signal relays for the circuits have been developed by Siemens & Halske from the well-tried magnetic switches used in the electro-mechanical interlockings. A type of mechanism has gradually been evolved which consists of a single unit with ten contacts. This signal relay, the K 50, has proved most successful and is used exclusively in the newest Siemens circuits. It can also be used as an interlocking relay by connecting two of the relays together mechanically. A large number of interlocking relays are used in the circuits and elsewhere where a faulty disconnection of current from a relay produces no breaking of the contact. The firm of Standard Elektrik Lorenz does not use special signal relays but telephone relays in which an even movement of the contact springs is produced by means of a grid of synthetic material. Interlocking relays are produced by the mechanical connection of two normal relays.

In order to protect the circuit against sticking of the contacts, circuits which are particularly important are protected by doubling the contacts in front of and behind the relays or by doubling the relays in front of and behind the contacts, the correct operation of the contacts being checked in one of the subsequent switching operations. The number of circuits used is therefore rather greater than in comparable installations in England and America operated with the usual large relays. This is compensated for by the smaller amount of space required.

Insulated wire of 0.6 mm. diameter is used to connect the relays, while insulated wire of 0.9 mm. or even 1.4 mm. (when greater distances have to be covered) is used for the cables running to the outside installations. The wiring inside the building is contained in cables carrying a maximum of 60 wires, while the wires to the outside installations are in cables containing up to 200 wires and sheathed in plastic. The terminations inside the building are all soldered but those outside are attached by means of conventional terminals. In future however the large majority of these will also be soldered. Where necessary the cables inside the building are terminated on intermediate distribution frames to which the wire-ends are connected one above the other, while the cables outside run into cable terminal boxes or flat cable distributors flush with the ground. From here they are distributed into smaller cables which eventually run as single wires to the points, signals and track circuit terminal housings.

The points are operated with four wires by three-phase current at 380 v. which is conveyed directly from the signal relay room. The position of the points is checked constantly, using the same wires and a 60 v. direct current. A 220 v. alternating current is used for the signals, and this current is also connected by the relays in the interlocking. It is converted into 12 v. at the signal. The track terminal housings of the insulated track sections are also supplied with a 220 v. alternating current which is converted to about 6 v. in the housing. At the end of the track circuit the voltage, which has usually been reduced to 2 v., is increased to 20 v. and conducted from there by means of the track relay into the signal control room. On sections on which no electric trains operate a frequency of 50 c/s is used, while on the electrically operated sections (16⅔ c/s, 15,000 v.) a frequency of 100 c/s is used. The switching devices for the supply and distribution of the current are assembled in relay racks. When the mains supply fails a battery takes over for a short time, supplying current to a special converter until a diesel generator is able to continue the supply of three-phase current.

3. Centralised Traffic Control

The direct control of points and signals in geographical interlockings is limited by the resistive and capacitative impedance of the cables. Because the cables are usually 0.9 mm. or 1.4 mm. in diameter the distance from the relay room to the points cannot be greater than 2,300 m., the distance to the main signal not more that 2,500 m. and the distance to the distant signal not more than 3,500 m. The German Railway authorities together with Siemens & Halske have now developed a remote control system for the operation of more distant points and signals.

The first of these installations was set up on the 12 km. section of line between Bebra and Cornberg in 1951 for the control of a cross-over in the middle of the section from one end of the section. The second of these devices was put into operation on the 100 km. long double-track line between Regensburg and Nurnberg. Ten intermediate stations are remotely controlled from the central control point in Nurnberg, while a station controller is located at a fairly large station in the middle of the section. He may only set his departure signals to " proceed " on the instruction of the central controller in Nurnberg. No other double-track line has since been equipped with centralised traffic control equipment. On single-track railways this system is used most profitably for the remote control of the train passing loops at the intermediate stations. A project is already under way for equipping the single-track line from Lübeck to Puttgarden—the new ferry station to Denmark—with remote control, as this line carries a very heavy traffic of 100 trains, including a large number of express trains.

The German railway authorities regard remote control systems as highly important for the connection of a number of closely situated stations and junctions to fairly large terminals. The first step in this direction was taken in 1954 when a junction point outside Wiesbaden for a number of lines carrying very heavy traffic was connected to the main station at Wiesbaden by means of a centralised traffic control system, so as to control the running of trains which often follow very closely upon each other, over a 3 km. long section of three-track line.

In 1957 the first large installation of this type came into operation in Frankfurt am Main. Seven local stations and junctions around the main station are connected into the system, and this will later be extended to a total of 20 operating points. A diagram of the whole track lay-out outside the station to a distance of 10 km. is shown on a large panel from which the movements of every train in the area can be observed. Two central traffic controllers sit in front of this panel and set up the routes for 1,850 trains every day, using a push-button control desk.

In the Siemens c.t.c. equipment an impulse code system is used which operates over two wires by means of telephone relays. Four relays are used for the dual code. Sixteen sets can be controlled in this manner, each of which is able to transmit 16 instructions or control indications which means that a total of 256 control indications can be transmitted in each direction. If a larger number of different commands are required by a particular signalbox the numbers of wires and appropriate transmitting devices must be increased. A total of 4 transmission lines is required by the Frankfurt control room for one of its complex junction points in order to transmit about 250 different commands and 700 control indications. Because the trains follow each other in such close succession the busiest transmission line has to carry about 8,000 transmissions daily. The depression of a push-button at the central control point operates a relay which first engages the wire and then operates the appropriate set at the receiving point according to the code allocated to it. The receiving point confirms the correct selection of the group so that the actual command can be transmitted and acknowledged from the other end. The line is then cleared. This process takes place within 1.2 seconds. If a number of commands are to be transmitted at once they have to be stored and transmitted in succession. The delay is not very great even when the number of commands to be transmitted simultaneously is considerable since the speed of the transmission processes is far greater than that of the trains.

It is not advisable to transmit these indications by means of electronic devices rather than relays since the speed at which electronic devices are able to transmit these commands is such that they could not be fully utilised and remote control by means of relays guarantees an adequate degree of safety. It has been found that in cases of failure of signals or points information should be transmitted very accurately so that the correct decisions can be taken when the safety of the interlockings has been reduced. Plans are already in existence for producing electronic devices solely for the transmission of information to control points, but at present there is no intention of replacing the relay control equipment at the actual central traffic control points.

C.t.c. could not be used over relatively long stretches of line and in large terminals were it not supplemented by visual train number indicating devices which provide the controller with precise information on every train which is travelling in his particular section. The train number indicating devices were evolved together with the centralised traffic control but in large railway terminals they are often used without the remote control equipment. The visual train number indicator shows the train number in accordance with the time-table by means of illuminated symbols on a ground-glass screen. This occupies two basic elements within the track diagram in the central control panel or the operating desk. Behind the ground-glass plate there are mounted a total of six groups each consisting of 10 lamps (1.2 w., 6 v.) and each switched on selectively by five relays in order to illuminate the six-digit train number. One of the ten lamps in each group lights up and throws its light on to the ground-glass screen through a stencil in front of it and two moulded glass plates covered by condensing and deflection lenses. An indicator field of this type is allocated to each station or block section. The train number is fed forward from the neighbouring station and appears in the furthest field of the central control panel as soon as the train approaches the terminal. It travels with the train across all the block sections on the panel until it is finally extinguished either automatically or by hand at the final point on the panel. The controller is thus presented with a clear picture of the movements of all trains within his control area. Train number indication is one of the most important and, for the German railways, indispensable features of modern signalling. It is quite indispensable for the centralised control of long sections of line or large terminals. Even when used in installations without c.t.c. it considerably improves the signalman's general view of the state of operations.

4. Fully Automatic Signalling Equipment

Geographical interlockings and centralised traffic control devices count as partly automatic equipment since a signalman initiates the process of setting up the routes, but the process thereafter continues automatically or in a manner controlled by the train only after it has been initiated in this way. In fully automatic equipment even the activities of the signalmen in receiving and utilising train indications are taken over by the train and used for setting up routes. Fully automatic equipment, e.g. automatic block signals, flashing light devices for level crossings, automatic train control at signals and stored point operation during gravity shunting, have been in use for a number of decades in certain regions. It is only in the last few years, however, that these devices have begun to be generally introduced into the whole railway network.

(*a*) Automatic Block Signals

Automatic signals controlled by the trains on track circuits began to be used very early in Germany on fast metropolitan railways with a very close succession of trains of the same type running at the same speeds. Their introduction into long-distance lines operating with different types of trains and vehicles running at different speeds took longer, at least in Germany. It was only after the second World War that automatic block signals together with the newly developed geographical interlockings began to be used more and more widely on long-distance lines. They can be installed at any required distance from each other along a line, and if arranged to the best advantage can increase the traffic-carrying capacity of a line considerably. Therefore the lines carrying a very heavy traffic of 150–300 trains (in both directions) were the first to be equipped with these signals. The success of the scheme in terms of economy and efficiency was such that the whole network of main goods lines is to be equipped with automatic block signals, route-relay interlockings being installed at the same time wherever possible, with or without c.t.c., to equip these important lines to carry a heavy train service. It is intended particularly to introduce this type of signalling in places where the lines are electrified.

The distance between the automatic block signals depends on the density of traffic on the line, and is calculated taking into account the speed of the line, the train load and the locomotive power. The distance thus calculated on the lines with the densest traffic is approximately equal to the braking distance of the train. In this case the signals follow upon each other at intervals of 1,000–1,300 m., the distant signal of one block signal often being situated on the pole of the preceding block signal. If the distance is greater than 1,300 m., special distant signals are set up at a distance of 1,000 m. The automatic block signals are not controlled by the approaching train but by the train which has just run past the signal. It is reset to " Proceed " as soon as the track section to be covered has been vacated by the train, and the following signal is set to " Halt." The first signal remains in the " Proceed " position until the next train has run past it. The signals are controlled by track circuits, the insulated sections of which can be at most 2,300 m. long. If the distance between two signals is greater than this a second track section must be connected and its free or occupied state transmitted to the same signal.

Over long track sections and where the rails are not able to be insulated, e.g. where they are mounted on steel sleepers, axle counters will be used in future for the control of block signals. After some initial difficulties had been encountered a practicable version of the magnetic axle counter was developed. It consists of impulse transmitters on the rails. Each wheel of the train, as it runs along, weakens a magnetic field in the impulse transmitter, thus controlling a relay. A meter in the signal-box or the relay box counts the numbers of axles which have travelled into and out of the section both at the beginning and the end of the section. It took some time to develop a device which satisfied all the operating requirements (simultaneous counting in and out, effectiveness at speeds of between 0 and 200 km./hour, resistance to vibration of the rail, to changes in temperature and to exposure to the weather).

Meanwhile experiments have already been carried out using an inductive impulse transmitter and an electronic meter. They promise to be successful.

(*b*) Protection of level crossings

In Germany on lines with a speed of more than 60 km. per hour all level crossings must be equipped with barriers or similar protection. The yearly cost of employing staff to operate the large number of level crossing barriers on the German railways (about 18,000) amounts to the considerable sum of 150 million DM. This sum could be reduced by the more widespread use of automatic flashing light equipment in place of barriers. Until recently, flashing light equipment was only used on minor single-track lines crossing busy main roads, and at the present time there are 2,000 flashing light installations of this type in use. On double-track lines the flashing light equipment is supplemented by a half-barrier which holds up the road traffic when a second, opposing train is approaching the crossing after the first train has passed through. Where the line crosses minor roads, e.g. country roads, an illuminated sign indicating " two trains " and situated beneath the flashing light is used instead of the barrier.

The research and development work being carried out on these installations which use barriers or illuminated signs has now been completed and large numbers of these devices will probably come into use during the next few years.

The flashing light equipment is not illuminated unless a train is approaching and is made visible to road users by means of a reflector in the form of a St. Andrew's cross. The red flashing light is switched on at least 29 seconds before the train reaches the crossing and flashes at the rate of 60 times per minute. On lines having a speed less than 90 km. per hour failures in the flashing light equipment are indicated to the train driver by means of a control signal situated at braking distance from the crossing, so that if the equipment fails the train may be halted quickly at the crossing and allowed to travel across slowly after all the necessary precautions have been taken by the train personnel. On lines with a higher speed the failure is not indicated to the train driver directly but to a neighbouring station where the train driver is informed of the failure.

(*c*) Train Control

On the German railways main signals and distant signals (connected to main signals and usually placed at a distance of 1,000 m. from the main signal) have only three aspects: these are the " Halt " aspect indicated by a vertical semaphore signal or a red light on the main signal, and the " warning " aspect indicated by a yellow disc or two lights placed obliquely (the right-hand light being higher than the left-hand light) on the distant signal; " Proceed " (at the permissible speed for the particular track section) by a slanting semaphore signal or a green light on the main signal and by the rotation of the disc to one side or by two green lights arranged obliquely on the distant signal; " Slow " (40 or 60 km. per hour) by two slanting semaphore signals or a green and an amber light arranged vertically on the main signal and by a semaphore arm slanting downwards to the right underneath the yellow disc or a green and an amber light arranged obliquely on the distant signal. The mechanical semaphore signals illuminated by propane lamps lasting six weeks at a time are gradually being replaced by light signals which are equipped with double-filament bulbs (12 v., 30 w.) in double-lens lamps fitted with one solid lens and one saucer-shaped diffusing lens. Only light signals are used in route-relay interlockings.

Main and distant signals on the tracks in very busy sections of line are equipped with inductive train control devices which prevent the train from running past a " Halt " signal. A coil mounted in the locomotive creates an inductive field with three frequencies. If the appropriate signal is at " Halt " the inductive field will be reduced by one frequency due to the action of the signal's permanent coil on the track. The weakening of the inductive field causes a relay in the train corresponding to the particular frequency to drop and the brakes are applied. One coil is situated at the distant signal and causes the brakes to be applied automatically if the train runs past this magnet while the distant signal is indicating "warning," unless the driver operates a vigilance button thus indicating that he has received the warning and intends to apply the brakes himself. However, if he has not reduced the speed to below 90 km. per hour 22 seconds after running past the distant signal, or if he travels over another coil situated 150 m. in front of the main signal at more than 65 km. per hour even though he has reduced speed, the brakes are applied automatically. If, in spite of all these precautionary measures, he does eventually run past the halt signal the brakes are applied immediately. This succession of control points ensures that the train can never travel more than 200 m. beyond a main signal at "Halt." All designs for track layouts assume this distance of 200 m. as the distance from the main signal to the danger point.

All locomotives with a maximum speed of 100 km. per hour and over running on main lines are fitted with these train control devices. Automatic train control is intended to be developed to a stage where the trains can not only be braked automatically but can also be started and accelerated. This objective will probably be achieved not by means of control at specific points on the line but by means of devices acting over the whole length of the track which will provide continuous train control at every point on the line, using the rails, a special cable laid along the track, or wireless signalling. Investigations into the operating requirements and technical feasibility of these devices have already begun but it will be some years before a safe and reliable form is evolved.

(*d*) Automatic Gravity Shunting

In contrast to train running, shunting movements within stations are not usually controlled automatically and carried out in accordance with a strict programme. Routes for shunting movements must therefore be set up by a signalman, whose work is considerably simplified by the use of route-relay interlockings and radio control devices. In the case of larger marshalling yards the very fact that these are run on the principle of gravity means that the wagons can be marshalled by automatic means, with a consequent reduction in the numbers of staff required and an increase in efficiency. The first installations of this type came into use about 30 years ago. Using this equipment, the programme containing the sequence of the wagons to be distributed can be stored according to the shunting programme for the entire train, in such a manner that the wagons to be shunted set up their own routes automatically. Hydraulically operated rail brakes of the Fröhlich-Thyssen type were constructed at the same time. After the war the storage system for point operation was improved and work begun on the automatic control of rail brakes. The old types of brake-control devices operated by hydraulic pressure were replaced by electrically-controlled oil-pressure machines with a shorter reaction time. The weights of the wagons and their rollability are measured during shunting before the wagons reach the rail brake and are correlated in an analogue computer with the data on the resistance of the curves and points of the route which has been previously stored, with information on the distance which the wagons have to run, obtained from a siding occupation indicator and with the data on temperature and wind conditions which are fed in by hand. From this information the computer calculates the required speed at which the wagon should run out of the brake and compares it with the actual speed which is measured by means of a radar device. As soon as the required running speed is reached the rail brake is released automatically.

In Germany rail brakes are usually situated at the foot of the gravity incline in front of a set of 8-10 tracks. On running out of the rail brake the wagons still have a certain distance to travel and in this section their speed may be affected by wind, different running characteristics, etc. They may not therefore arrive at their objective—the previous wagon to be shunted—at a speed approximately sufficiently closely to the required speed of 1 m/sec.—necessary in order to avoid damage to the goods carried by the wagons—for them to be coupled without additional shunting movements being required. When this type of brake equipment is used therefore trackmen are still required. The dangerous work which these men perform can only be taken over by small rail brakes situated on each track behind the last point on the gravity incline and connected to the computer. Research is continuing into the best type and layout of these brakes.

The German railway authorities are also continuing research and development work on automatic control systems because of the many various functions which this equipment is required to perform. Up to the present time automatic control equipment has only been applied in trial installations using certain parts of the equipment, but the first fully automatic installation for normal operation can be expected in the next few years. Altogether about 70 German marshalling yards are to be equipped with automatic control—a scheme which will prove extremely costly.

(*e*) Automatic Routeing of Trains

When the scheme for centralising the control of traffic in the region of the large main terminal at Frankfurt (Main) is completed the c.t.c. operators will be relieved of the duty of selecting train routes in accordance with a strict time-schedule. In spite of differences in speed, type and importance, the trains arriving from the different departure stations situated at various distances from the terminal must therefore be able to set up their own routes as far as possible according to the time-table. The wide differences between the types of trains operating in the Frankfurt region make it impossible for the correct selection of the route to be transmitted from a device mounted in the train, as is the practice on railways operating with trains of the same type which run at the same speeds within a limited network. Nor can trains be controlled in accordance with a rigid timetable because as they arrive from different directions and converge in bottlenecks, deviations from the order laid down by the time-table frequently occur. However, the train number indication system organised in Frankfurt as part of the centralised traffic control provides an excellent means of transmitting routeing instructions.

The first digit of the six-digit train number is provided with a special symbol for this purpose. This direction symbol follows the course of the train along the visual control panel and is transmitted to the local signalbox in such good time that a route can be set up without delaying the train so long as it does not conflict with another route.

If two or more trains are approaching a track junction at the same time, the instructions for setting up the routes for the second and subsequent trains are stored until the routes are clear. Routes which are possible simultaneously are selected from the stored aggregate of routes. In spite of the fact that the sequence of trains is greatly improved by this system, important trains can still frequently be held up by less important ones.

In order to resolve as rapidly as possible the difficulties which are bound to arise during the course of operations, the central traffic controller can alter the order of train running prescribed by the device. He is able to give preference to a particular train or to hold it up on a particular section of track by the operation of a push-button without interrupting the automatic process.

The devices for routeing trains automatically are not connected to the central control point but are actually situated in the local signalboxes. The centralised traffic control only serves to transmit the direction symbols as soon as the train number appears in the second or third block section before the junction point. The symbol is stored at the local signalbox until the actual approach of the train is announced by track circuit. A special detection circuit checks that the transmission of the direction symbol corresponds to the announcement of the train before the instruction for preparing the route is passed to the storage and selection relay circuit.

The scheme for the automatic routeing of trains was first conceived in 1955 and the first trial operation carried out on December 5th, 1957. Since April 1st, 1958, the first junction in the Frankfurt region has been fully automatic. The other six remote-controlled junction points followed in 1959/60. From the very first the installation has run almost without failure, and as a result of thorough development work has proved highly successful. When trains follow upon each other in very close succession, routes can be set up far more quickly than when c.t.c. alone is used. The central traffic controllers are relieved of much of their routine work and only intervene in emergencies when they can see from the visual control panel that a difficult situation is liable to arise. The installation of this equipment has meant that for the first time a great deal of the purely repetitive work involved in railway working has been able to be reduced, and the necessary duties can be performed by a small number of highly efficient control personnel. The introduction of automatic train steering means that the running of trains over a whole railway network can be controlled from large central control points. The installation at Frankfurt was designed and equipped to deal with traffic control at the most complex track junctions and under the most difficult operating conditions, and is prepared for all contingencies. It has been designed to perform all the necessary control functions in the simplest manner. Schemes are in hand for installing automatic train steering apparatus at other terminals either with or without centralised traffic control, and for applying it later to track sections between terminals situated at some distance from each other.

(*f*) Conclusion

The advances made in signalling by automatic means reveal that when the earlier types of equipment have been improved and brought up to date by means of modern engineering methods, train and shunting movements can be controlled according to a pre-set programme and considerable economies in manpower made. It is obvious that the engineering techniques peculiar to the railways give them immeasurable advantages over other means of transport. The automatic control of many railway operations has been possible because of the fact that the vehicles are confined to rails, and the tracks have required no special supplement. In all other forms of transport in which vehicles are able to move freely over a surface or space, some sort of contact must be provided as a substitute for the rails as a means of controlling the vehicle automatically.

If the schemes envisaged for controlling even the motive power of trains by the action of signalling equipment or other automatic devices independently of any human control prove successful, the railways can look forward to a future in which automatic equipment takes over all the repetitive work at present undertaken by the control personnel whose only remaining duties will be to control any deviations from the pre-set programme and initiate any special procedures which may be required.

Although the significance of the railways as a means of transport has been greatly diminished by the advance of the rival road and air services, in this age of increasing automation the railways are capable of developing into the most modern means of transport.

DISCUSSION

Mr. Owen: Thank you, Herr Kümmell, for the excellent reading of your paper. Would Mr. Brentnall please open the discussion?

Mr. Brentnall: Mr. President, Herr Kümmell, gentlemen, the Author has given a very interesting account of the development of signalling on the German railways for a number of years and I think that what he has told us shows why the development in this country has been different somewhat from Germany. In this country, for many years signals have detected points on the ground, both for running and shunt moves. It has not been necessary to divide up the signal operating personnel so that they could see the position in which the points were lying.

The route was held by facing point lock bars originally, and in recent years by track circuit. It has also been the practice for full interlocking of signals to be provided for running and shunt moves and trailable points have not been considered necessary. In general, there has been one signalbox per station or junction, with two or more for larger layouts.

The development of relay interlockings in Great Britain dating from 1932, has been for such equipment to be provided at the larger layouts. Smaller layouts have been fully signalled in the past and, in conversion to modern colourlight signalling, have been provided with electro-mechanical frames or converted to controlled ground frames.

Centralised traffic control operating with relays has not been considered suitable in this country in view of the dense traffic. Electronic remote control has been introduced recently, utilising transistors which give high-speed working. It is my opinion, perhaps contrary to Herr Kümmell's, that, even if the fullest advantage of this high-speed working is not utilised, then this arrangement can give very satisfactory results.

Fundamentally this system comprises two synchronously operated counting chains, one at the office and one in the field. The number of steps is equal to the number of two-position devices to be controlled or the number of functions to be indicated, whichever is the greater. Two frequencies are used for controls and another two for indication. Operation occurs when the signalman presses his push-button.

All stepping, counting, chain actions, etc., are carried out by transistors, relays being used solely for the final registry. The rate of operation and counting is very rapid, as high as 500 per second. I have only used about 100. The safety interlocking is effected at the site, the chain action merely being the control. Another method of remote control where the distances are not so great has been for a direct wire system to be adopted. Separate twisted pairs in telephone type cable have been used for each indication and control function, with miniature type post office relays for the line circuit.

In connection with some of the details which Herr Kümmell has mentioned, I would like to refer to one or two. In Great Britain, the Regulator does not usually have panels or push-buttons to give instructions to the signalmen. Any instructions are verbal. Herr Kümmell refers to "particularly important circuits" being protected by the doubling of relay contacts. I would like to know what is the criterion for such a circuit; when does it become "particularly important? "

Regarding wire terminations, I noted from Herr Kummell's paper that the general arrangement is for them to be soldered. It is different here, where, with plug-in relays the general method is for the wires to be taken to the backplate with a form of spade connector which can only be removed by a special tool. We feel this is more satisfactory than soldering, particularly for testing or alteration.

The Author mentions the use of 100-cycle circuits in electric traction areas operating at 15,000 volts, $16\frac{2}{3}$ cycles. Has there been any difficulty from induction effects in this connection, and what methods of overcoming difficulties have been used?

I am not quite clear on the description of the direct control of signals. He mentioned in the paper that the direct control for a main signal could be taken 2,500 metres and to a distant signal 3,500 metres. Why the two distances?

I was interested in the two examples of the C.T.C. lines. The Bebra-Cornberg and the Regensburg and Nurnberg—I have seen them both. I believe the Bebra-Cornberg installation was primarily put in to give both-way working on a heavy gradient, so that passenger trains could pass heavy freight trains on the uphill gradient. The other installation, Regensburg and Nurnberg, was, I think, very praiseworthy as an experiment. I rather gathered that it is not proposed to pursue this form of control for double line. Why?

At Frankfurt, the description showed the two central controllers sitting in front of the main panel and Herr Kümmell mentioned that these two controllers operate the routes for 1,850 trains every day. Presumably, that was before the automatic working was brought in with the remote control. Could the Author confirm that?

It may be of interest to the Author that in a scheme recently brought into use at Manchester, a route relay interlocking, three signalman operate a panel, spaced equally along it because the layout lends itself to that division. Three men operate it and there are 1,845 booked movements in 24 hours, plus 50 unbooked engine movements.

The train describers with four digits of which we saw pictures are very interesting and similar units are being used in this country, with the lens and stencil system, but recently it has been felt that smaller indications were desirable with miniature type panels and other methods of giving the four digit descriptions are being adopted.

There are various methods, such as edge-lit perspex sheets or rotating discs or cathode tubes.

Magnetic axle counters interest me very much. Do they operate at all speeds from the slowest to the fastest, or do they have to be placed in installations giving certain degrees of speed?

Finally, we are interested here in automatic level crossings. We are endeavouring to get some installed, but we are at the stage where the authorities are giving us different instructions. I was interested to note that in the German railways, half-barriers are only used where there are double lines and for the purpose of warning the road traffic if there is a second train coming. In this country, if we use automatic half-barrier types, we should have to have them there even with a single line. Again, there is a similarity in the "2nd train coming" notice. We shall have to give an illuminated notice which says "2nd train coming".

Herr Kümmell: I thank Mr. Brentnall for his questions. I said that doubling of contacts in circuits is used in all cases where the circuit has to be closed for security conditions. In all these cases we double the contacts or we double the relays before and behind the contacts.

All relays in German installations are concentrated in relay sets and these sets are plugged in. The connection of wires to the ground plates is soldered.

The C.T.C. Installation Bebra-Cornberg was a trial for both way running on one track of a short double line and for remote control of two crossovers in the middle of the line. Regensburg-Nurnberg installation was a trial for a long, double track line but the effect upon personnel is not so good and it is not likely that we shall have another installation of this kind.

The axle counter is developed in such a manner that a wheel can stand on the magnetic impulse transmitter or can pass it at high speed. It was not easy to attain this stage and we spent many years in finding out the conditions under which the equipment works well. Now we are quite satisfied.

Half-barriers are only used on double-track lines because we consider that normally the flashing light is sufficient indication for car drivers. The barrier is only a sign that a second train is also approaching and drivers must wait for this. Most drivers also prefer half-barriers for single lines and it is not quite clear what will be the result in the next few years. I myself believe we should have half-barriers on single track lines. Have I replied to all your questions?

Mr. Brentnall: There is the point about 1,850 trains at Frankfurt.

Herr Kümmell: 1,850 trains in 24 hours are running in the whole area of Frankfurt. At first we put into operation the C.T.C. installation of only three of the seven junctions without automatic train routeing. After we had finished the automatic routeing of one junction we put into operation the C.T.C. of the fourth junction. Now the four junctions are working automatically and the rest will follow in 1961.

Mr. Knotts: Herr Kümmell, gentlemen: I would like to express my own appreciation of Mr. Kümmell's timely paper. I think if I were to make an overall appraisal I would say it indicates above everything else that an intelligent application of modern equipment can enable the railway system of most countries to be more effective in competing with road and air transport, and particularly in the matter of freight traffic. The paper expresses optimism therefore in my view for the future of railways and is factually set out in a manner which indicates clearly the natural development and application of automatic operation in its various forms. I would suggest that the operating departments will come to realise more and more that they can be much more revolutionary and progressive in the services they provide, both in number and in type, to make for intensive timetabling.

There are many interesting points in your paper, which I would like to discuss, but I would confine myself to only a few. You refer to the trailable point machine and that has been in use in Germany for many years. Is it the intention to continue with trailable machines in the new signalling installations?

Herr Kümmel: Yes.

Mr. Knotts: Regarding centralised traffic control on single lines, I was wondering whether you were arranging for loops to be long enough for trains to pass each other at speed. In other words, when passing in the loop do both trains keep moving or is one of them brought to a standstill?

Herr Kümmell: The length of a loop on the single line is normally 750 metres. One train must stop, the other passes. In the C.T.C. projects we are considering using a longer loop (about two or three kilometres), between two stations to enable trains to pass without stopping.

Mr. Knotts: Would that be on double lines or single line?

Herr Kümmell: This is a short double line between two stations within a long single line.

Mr. Knotts: I take it you would adopt electronic means where you say it is not advisable to transmit indications if it were financially sound to do so, and that it is not a technical point you are making?

Herr Kümmell: At the moment it is a technical point. We had decided to transmit commands for signals only by relays, because we know that relays are safe enough, but we do not know whether the electronic devices have the same safety. It is possible that we shall have a different opinion in a few years.

Mr. Knotts: You speak of the signal being replaced or put to "Halt". Is that done with the first wheel of a train or the last wheel? Is there an overlap?

Herr Kümmell: The trains put the signals to "Halt" position with the first axle about 50 metres behind the signal, or sometimes more.

Mr. Knotts: Is there any "proving" of the "Halt" indication aspect in any way, i.e. that the signal has, in fact, displayed the red aspect after showing a less restricting one? Then, on the use of axle counters, have you found they are a necessity for enabling the wider adoption of long-welded rails?

Herr Kümmell: The track engineers require them. We have steel sleepers we cannot insulate and we must change them but with axle counters we need not do so. They are more expensive, though, and we have now in construction one installation with axle counters in the points. All track circuits are changed to axle counters but we do not know yet if this is practicable.

Mr. Knotts: You have spoken of the more continuous control of a train. What is, in your view, the main advantage of this rather more precise control of the train? What is the principal objective? Is it a question of safety only or is it to do with better running of the train? It is for conveying instructions continuously to the drivers of the trains presumably?

Herr Kümmell: Experiments are being made in a technical University in Western Germany in studying the possibilities of transmitting impulses between a cable along the track and the locomotive. It is intended at first to give continuous instructions to the driver and later to drive the train automatically. We hope to attain better running of trains.

Mr. Knotts: Is your main consideration here one of safety?

Herr Kümmell: Safety is also a very important consideration.

Mr. Knotts: On the question purely of communication, I take it there is a telephone for communication from the driver?

Herr Kümmell: It appears possible, to use the transmission for communication purposes, but it is not intended to do so.

Mr. J. P. Coley: I would like to refer to page 168, where the Author mentions that, "In order to protect circuits against sticking of the contacts they adopt the arrangement of doubling the contacts in front of and behind the relays", and he goes on to say that, "The correct operation of the contacts is checked in one of subsequent switching operations". This seems to be a considerable simplification of my understanding of the actual arrangements adopted, and I have looked up Mr. Rehschuh's paper which he gave to the Institution in 1954 and I see that he states that the German Federal Railways Specification stipulates that all relay armatures must be proved in the de-energised position. In the course of the discussion he said that all relays are so constructed that if any contact becomes fused by excessive current, the relay mechanism will be held in an intermediate position in which all other contacts will be open; thus, if it is an energised contact which is welded and the relay is then de-energised, the arrangement would be such that de-energised contacts would not close and that all other energised contacts would open. Consequently with the de-energised contacts open the relay would not be proved released and subsequent circuits would not be closed. This arrangement provides the proving called for by the German Federal Railways.

I do not think that the use of two contacts in series in a circuit provides any protection against welding and this is borne out by Mr. Rehschuh's further remarks when he said that one of the principal reasons for using two contacts, one on either side of the relay, was to protect against extraneous currents.

The Author seems to suggest that Electronic C.T.C. Systems are not used because they are too fast, but I do not feel that this is a sound reason for not using such equipment, as it must always be an advantage to use components which are static rather than to use relatively delicate relays.

I infer from the paper that the German Federal Railways do not favour Electronic C.T.C. because it is not sufficiently safe, but I must point out that no C.T.C. System is intended to be safe; all safety must reside in the external interlocking employing signalling relays. It seems more probable that the German Federal Railways feel that Electronic Equipment is less reliable than Relay Equipment, and that indications received from remote locations cannot be relied upon to the same extent with Electronic Equipment as with Relay Equipment. There are no statistics available at the present time to enable one to decide the relative merits of these two systems from the reliability point of view. The German Federal Railways require to have accurate information if a failure has occurred in the signalling or point operating equipment. It seems to be stretching matters a little far to assume that one is going to have a failure of the C.T.C. System at the same time as such an external failure, thus giving false information to the operator.

With regard to the length of track circuits, I notice that in Germany you go to lengths of 7,500-ft. This is very considerable and I wonder what determines the maximum length of a track circuit. In this country for a given value of ballast the length of the track circuit is determined solely by the requirement that we need to have shunting resistance of half an ohm when the track circuit is dried out to cause the track relay to release.

Herr Kümmell: The first question: In this paper the description of doubling of relay contacts is simplified. The explanation in Mr. Rehschuh's paper is more correct.

The second question: In the case of a failure in the signalling or point equipment, we also suppose that no fault of C.T.C. equipment appears We find out more failure of interlocking installation, and very few troubles of C.T.C. equipment. In the case of failure of home signal, the controller has to give an emergency signal or an order by telephone to the driver. Before he can do so, he has to look at his panel, whether the train can pass the signal in sufficient safety. In one case, the C.T.C. transmission of information was not exact enough, the controller cleared a false emergency signal, the train passed the signal and endangered another train. There was no accident, but we learned that information must be transmitted with high safety. In this case, we doubled the transmission of this information.

Mr. Coley: Was that with the relay system or the electronic system?

Herr Kümmell: We have only relay system and that was a failure in one of the circuits.

We use normal timber sleepers in tracks with track circuits but more and more concrete sleepers. New timber sleepers normally have a better resistance than concrete sleepers. In any tracks with concrete sleepers we must divide the proposed length of 2,300 metres into two shorter sections. In most cases the total length was sufficient.

Mr. Woodbridge: Mr. President, gentlemen, I was very interested to see Herr Kümmell come over here and give us the paper on modern German signalling. I first met Herr Kümmell some years ago when he took me round the big Frankfurt installation and it has given me, and I am sure all of us, a great deal of material to think about. The idea of an exceedingly large installation in a very busy area covering the control of every movement in that area. It is the conception of Frankfurt and, indeed, the more modern large German installations that is a little different from the conceptions we have of the control of an area from a signalbox. I think we have to realise, for example, that all the controllers, engine controllers, train controllers and all these functions are included in the signalbox, a thing which we do not do ourselves. So, when you get in a large German signalbox like Frankfurt, the first thing that is noticeable is that, where we would have five or six people in a box of that size they have something like 16 and I just mention that to try and correct the impression that they have to have a higher number of people than we do ourselves. I think, Herr Kummell, it would be quite true to say that you do use a few more personnel for operating the actual signalling than we do in this country, but that is the way we grew up. I have been discussing this with the German signalling authorities recently and they are pushing all their endeavours into reducing the number, so it is evident that some time or another we shall reach a common denominator.

I do not propose to go into the details of this paper, because I have not had the chance of reading it and I have had to try to absorb Herr Kümmel's most interesting descriptions while he has been giving it. One thing that puzzles me at the moment is that he mentions this figure of 1,000 metres between the distant signal and the home signal. Surely the braking distance must be longer than that and I wonder if you could amplify that question for me. I am speaking, of course, for your high speed lines and not the 60 km. lines.

Another thing that is most interesting in Germany, I think, which is different from this country, is that they have been able to use long-welded rails on timber sleepers and my civil engineering colleagues tell me that is because they have more timber sleepers per rail and therefore a stronger track. I suppose you have a great advantage there in getting these long-welded sections in and it is most noticeable that you get mile after mile of long-welded rails. I would like to ask, as you have to have expansion joints at the ends of these long-welded rails, do you have any special arrangements between the plotting of the signal positions and the plotting of the expansion joints?

We have a great advantage, gentlemen, in this respect, that Herr Kümmell is a civil engineer as well as a signal engineer and he has now taken over the maintenance of bridges and so on.

Another question I would like to put to him is, with his experience with concrete sleepers, this is diametrically opposite to what we have had. In fact, with insulated concrete sleepers we have been able to get very much better track circuit working than with timber sleepers and I do not know whether you have adopted any type of insulated sleeper fastening in Germany.

Well, gentlemen, I am quite sure that other people want to speak, so I will thank Herr Kümmell very much for coming over to give us this paper.

Herr Kümmell: I believe you use fewer people for operating mechanical signal installations and also modern interlocking plants. We want to reduce generally the high number of personnel by new installations, but also to diminish the working of staff in the new interlocking plants by means of automatic equipment.

The German Federal Railway has fixed the braking distance up to 1,000 metres. Trains must have such a braking equipment that they can be stopped after passing a distant signal in "Warning" position. If the braking equipment is not sufficient, e.g. there are too few wagons with air brake installation in a freight train, the speed is limited. Express trains should have extra magnetic braking equipment. Therefore the distance between main signal and distant signal is fixed to 1,000 metres on high speed lines, to 400 metres on lines with speed up to 60 km. per hour. In these minor lines we only use distant signals in curves.

Long-welded rails must be interrupted by insulated joints 50 metres behind an automatic block signal. Permanent way engineers do not like these joints and want to use axle counters. If the insulation of these joints fails, the signal is set to danger. There are no other arrangements.

We have very good experiences with track circuits on new timber sleepers, but these do not retain the resistance over all the years. Normally concrete sleepers have the same resistance as new timber sleepers and retain it. Many years ago we used a form of concrete sleepers with less insulation. They gave us the difficulties mentioned before. But now we use very good concrete sleepers with insulated rails fastening.

Mr. Cardani: I am also one privileged to have been shown over the Frankfurt installation by Herr Kümmell. I was greatly impressed both by the size and by its technical excellence, and most of all by the intriguing method of automatic routeing of the trains. Would Herr Kümmell explain whether the routeing digit, the first digit, is only applicable locally in the particular area and has to be set up again when the same train reaches another area where automatic routeing is required?

Herr Kümmell: Today the routeing digit for a train is only used in the Frankfurt area. Later a similar interlocking plant will be erected near Wiesbaden, about 40 km. away from Frankfurt. Then the routeing digit in the Wiesbaden area will be another one as in the Frankfurt area and will be changed automatically in the middle of the line between the two areas, but until now we have not decided how to change the digit.

Mr. Aldridge: Mr. President, Engineer Kümmell, gentlemen: I had the privilege of spending six months in Germany studying signalling in 1928 and learned a little about some of the big differences that were in existence in those days between German signalling practice and British and other railway practice at that time. I have therefore always been very interested in the German railways and very impressed by the excellence of their service. So it therefore gave me very great pleasure to read and to hear also from Engineer Kümmell the fact that they have started to introduce the route relay interlocking just after the second world war and they have already got 400 small interlockings in service now. My first question is when you use the term "geographical interlockings", as in Section 2 of your paper does it include the "route relay system" as we know it over here or do you reserve "geographical interlockings" for the latter type you are now introducing which I think you have already called "spurplantechnik"?

Herr Kümmell: "Geographical interlocking" is the translation in English of our word "gleisbildstellwerk". All relay interlockings with the track diagram have the name "gleisbildstellwerk" which when translated literally means "track diagram interlocking". We call it normally push-button interlocking. Both techniques you speak of are of this type including the newest development of circuits.

Mr. Aldridge: Yes, I understand that the latest type where you arrange the circuits as you might say "geographically", is certainly the "spurplantechnik", but do you include what we know over here as "relay interlockings" in what you term "geographical interlocking"?

Herr Kümmell: Yes.

Mr. Aldridge: The second question is with regard to level crossings. As Mr. Brentnall has said, level crossings are of great interest in this country. We are all very disappointed at the slowness of introducing them but there are certain difficulties. I cannot see from your paper that you have any limits as to where you can install the automatic installations. Here we are not permitted even now to install the automatic installations anywhere irrespective of the amount of road traffic and/or rail traffic. In Germany, are you permitted to install automatic installations whether of flashing lights alone or with half barriers, on all crossings, irrespective of the density of road traffic and/or rail traffic?

Herr Kümmell: Normally it is allowed by law to do so, but in special cases it is an agreement between road and railway.

Mr. Tyler: Mr. President, one thing that interests me in Mr. Kümmell's paper is the automatic train control and the conclusion that has been drawn after it has been installed that the line is safe for 200 metres past the signal. Do I understand from that you recognise 200 metres in Germany as what we would call in this country an overlap, and if you do, does that mean that your interlocking ahead of the next signal allows for an overlap? Is your interlocking extended for 200 metres beyond the next signal?

Herr Kümmell: We lock points and include flank protection 200 metres beyond the signal.

Mr. Tyler: Thank you. That being so, could you tell me, sir, where in the geographical circuitry to which you made some reference is the interlocking necessary for the 200 metre overlap or is it "free circuitry"?

Herr Kümmell: The overlap interlocking is in an extra set in the latest installations.

Mr. Tyler: I was rather interested in the hump-yard layouts that you showed on the screen, particularly as there appeared to be no primary retarders. Is that normal practice?

Her Kümmell: We have only retarders after the dividing of the tracks. Therefore we have difficulties to give a clear destination to the moving wagons.

Mr. Aldridge: May I say something with regard to that last question as there may be a little misunderstanding. My view of the picture was that you had one section of a normal retarder in the sorting siding and then it was followed by seven special small retarders but that the normal retarder was not a group retarder because it was in the sorting siding itself and therefore I presume that if that layout was used there would be one 10 metre retarder followed by, say, seven smaller retarders in every siding. In addition, I believe there would also be what we call the group retarders but there will not be a primary retarder in addition to this. Would you correct me if I am wrong?

Herr Kümmell: You have your first retarder more towards the hump and the second on the more level ground. We begin with your second retarder and want to use a further retarder in the beginning of the sidings. It is only a trial. We hope that we can solve this problem exactly, but it would be very expensive because we would use in a big marshalling yard about 50 of the siding retarders. Two months ago I saw a trial installation on the Russian railways. They use one retarder on the hump, then a group retarder at the same place as you and finally a small retarder in the beginning of the sorting siding.

Mr. Tyler: As I understood your description of the marshalling yards, you show the marshalling yard with only group retarders and another system which I understand to be experimental, which I think is called the Grassman system and which I do not understand to be associated with the marshalling yard layout which you had shown previously.

Herr Kümmell: On the layout I showed these retarders were not drawn, only one group of retarders. The Grassman retarders you have seen are a trial we want to have in the near future.

Mr. Aldridge: This is a subject which, as all railway men know, is of great importance to us in this country. I would therefore like to be clear on this. In the picture of the Grassman you showed, as I understood it, a short normal retarder of about 10 metres in length followed by seven small ones in each siding. Is that so?

Herr Kümmell: Yes.

Mr. Aldridge: Thank you. We did not see anything in the picture of what happened in the switching area between the retarders and the hump. Do I understand there are no other retarders at all between those in the picture and the hump?

Herr Kümmell: No, there are the normal group retarders. The Grassman retarder which I have shown you could be the solution for the future --we do not know! We want to test one short retarder like the first in the picture, alone without the special short retarders in the background of the picture because it would be necessary to change the whole profile of the sorting sidings using the Grassman retarders and that would be very expensive.

Mr. Owen: Well, gentlemen, I think you will agree with me that it is one matter to stand up here and read a paper about your own affairs and railway experiences, in your own language—and quite another matter to write a paper in, to us, a foreign language, have it translated into another language and read it to people who do not understand your own particular idioms and ways of setting out explanations. I think Herr Kümmell has given us a paper which will be of great value to this Institution in the future.

In the reading of the paper, I detected one common feature, not common just between us and Germany, but between all our Regions and London Transport. He stated in one place "costly". This is a common experience to us all. Thank you, gentlemen, for your discussion, and thank you very much Herr Kümmell for coming so far to read to us such an excellent paper. I would ask you all to express your appreciation in the usual manner. This was carried with acclamation.