DISCUSSION.

Mr. H. M. SAYERS: I desire to make one or two remarks for the purpose of obtaining information. I do not understand the small amount of energy available for the relay. The potential between the rails is stated by Mr. Brown to be from 2 to 5 volts, 3 volts usually. With from 3 to 5 volts available between the rails, 2 or 3 watts, at any rate, should be available for the relay coils; and since the relay is not like a telegraph relay, in which the time constant is important, but may have a relatively large mass and therefore be wound with a large number of turns of comparatively large wire, there appears to be no particular reason why such a construction should not be used, and more certain action would seem to be secured. The difference between the "drop failing point" and the "pick-up failing point" Mr. Brown tells us has been reduced to nil. The telegraphic practice of using a relay in which the moving part does not make any material difference to the reluctance of the magnetic circuit seems to be the right way to get over the difference mentioned in the paper. Probably a moving coil relay would be a good device for the purpose. To get the greatest sensitiveness and to fulfil the conditions that are required in these particular circumstances, a polarised relay is desirable. I should like to ask if Mr. Brown has noticed any critical point in the voltage to be maintained between the rails. Claude, in an interesting paper read before the International Society of Electricians in 1900, dealing with the question of electrolysis due to stray tramway currents, cited a large number of experiments which showed that, for low voltages, earth resistance between rails and buried pipes acted as a metallic resistance—that is, it appeared to have a definite resistance, and the current through it varied directly with the applied potential up to a certain point. Beyond that point there was an electrolytic or polarising resistance. Consequently it would seem that, if the potential between the rails is maintained a little above the polarising point, it will be much steadier under differing conditions of weather and "ballast conductivity" than if it is below that point. That point will probably be about 2 volts, or perhaps a little higher. Mr. Brown may know something about this. Mr. Sayers.

Mr. W. J. THORROWGOOD: I think some objection might be taken to the term "ballast resistance" as used in the paper. In the track circuit the current passes from one terminal of the battery through one rail to the relay, and back through the other rail to the battery. Any current passing from rail to rail without going through the relay is in the nature of a leak, and in general electrical language the resistance of that leak path is known as the insulation resistance. In the literature of the subject we are discussing, it is called the track circuit insulation resistance. It seems to me that is a better way of regarding it, seeing that we are new to the subject. Then, again, the term "ballast resistance" is not generally applicable, seeing that, in some electric railways at any rate, there is no ballast. On steam roads, where the track circuit Mr. Thorrowgood

Mr. Thorrowgood.

is used, the ballast is cleared away from the top of the sleepers, and consequently you might speak of the "sleeper resistance." In any case, in these days of standardisation I think we should keep to the same term for the same thing used in different cases. With reference to using the difference of potential, it has been the practice hitherto to speak of the number of milliamperes which will actuate the relay. From the theoretical point of view it may be well to use the difference of potential when making your calculations to set out your system, but I think it will be found in practice easier to adjust your relay by means of the current passing through it rather than by the difference of potential on its terminals. With reference to the difference of potential of the storage battery, although the storage battery difference of potential may be allowed to vary 10 per cent., there is a minimum difference of potential which must be decided upon, below which your variations must not take place. For instance, you may go from 2 to 2·2, but not below 2. Coming to the rail resistance, as the paper says, it should be negligible. So it may be for 330 ft., but when you come to 2,000 ft., the resistance of the rails themselves is six times as large. Taking the resistance of a length of rail as 0·18 ohms—and that is about right for 1,000 ft.—the current received by the relay is about 1¼ per cent. less than if you left the rail resistance out of calculation altogether. That may be important if you are working near the margin, and in the figures given in the paper there are only 8 milliamperes in excess of the 50 necessary to actuate it. Mention is made in the paper of possible interferences of the track circuit by extraneous currents on electric railways where they take a certain amount of care to avoid them. I think the track circuits on steam roads are just as likely to be affected by these extraneous currents as are electric railways, especially if the track happens to be in proximity to an electric tramway. You have always the liability, at any rate, of having a difference of potential of 7 volts on the extreme ends of your electric tramway. I think the power, or the quantity, of these stray currents is rather more than is sometimes thought or expected. In one case a little while ago I found that from a rail to a point twenty yards distant there was a current of 95 milliamperes passing, and in other cases I have found a difference of potential of half a volt in a distance of a mile. In cases that have come under my notice where instruments have been affected, the difference of potential must have been 2 volts at the very least, and probably 4. It appears to me that this question of the interference of tramway currents is rather important. In London it is well known to telegraph people that there are many so-called earth currents flying about. With the advent of electric tramways and railways, the necessity may easily arise of having to insulate the track more carefully, or it may have to be insulated altogether if we are to avoid interference with the track circuit and the signalling. Alternating currents may be used in some districts to overcome the trouble. It may be a remedy, but the real remedy, it seems to me, rests with the tramway companies to provide efficient copper returns, so that their stray currents shall not affect other people using the earth return. Possibly, if they did so, their running charges might be a little more economical, and at the same time it would be advantageous to those using the earth as a return. Mr. Thorrowgood.

Mr. E. C. IRVING: I do not think there is much I can say in criticism of the paper, which is very clear to me, probably because I have had a lot to do with track circuits. There are one or two points I should like to mention with regard to the wooden block joint. So far as my experience goes, I have seen a wooden block joint pulled apart about 2 ins. in the morning after a cold night through the contraction of the rails, and then close up again through the expansion of the rails as soon as the sun came out, so that I do not think a wooden block joint itself is quite strong enough for railway work. It would be all right so far as the lateral stress is concerned, but not for the contraction. There is another point which is not very important, and that is the use of the copper bond. I think galvanised iron is rather better than copper, because there does not seem to be so much electrolytic action between the two pieces of iron as there is between the copper and the iron. This action, I think, where small voltages are concerned, is rather detrimental. It may be interesting to the members of this Institution to call their attention to the fact that the use of the track circuit in this country has passed the experimental stage, there being over 300 miles of it in use on various railroads, where it is giving every satisfaction. Mr. Irving.

Mr. F. GILL: The remarks I have to make are more in the form of questions. There are a number of points in the paper that I have not been able to follow at all, so that I thought if I put some questions to Mr. Brown it might assist others who are in somewhat the same difficulty as myself. With regard to the question of the design of the relays, I do not see at the moment why he wants to operate his relays with such a small expenditure of energy. He says on steam railways a relay should work with no more than 0·015 of a watt. Then further on in his paper Mr. Brown talks about economic working, but I cannot see that economy of current in the track circuit can be a very important point. I should have thought you could have afforded to spend energy rather liberally if it produced a safe result, remembering that there is a train at the back of the whole thing, and that if there is trouble it may be serious. Then with regard to the ballast resistance, or the leakage circuit, as one speaker called it, I do not see in the paper any definite figures under that heading. We get various illustrations saying that it may be one thing or another. On page 115 Mr. Brown says it may be a 333 ft. circuit at 2 ohms per 1,000 ft., or a 2,000 ft. circuit at 12 ohms per 1,000 ft. One would like to know what figure he actually gets in practice. In the same way, what is the resistance actually caused by sanding? I rather find all through the paper an absence of definite figures which one can seize and work on. With regard to the relay contacts, I notice that they are carbon and platinum. I take it that those are the local circuit contacts; but the reason given for the use of carbon and platinum contacts is so as to give freedom from lightning discharges. It is not very apparent to me why that should be the Mr. Gill.

Mr. Gill. case. I should like to know what is the pressure on the back contacts of the relay. When the relay has fallen back, when it is shunted, I understand there is a series of back contacts made, and there is no mention made as to what pressure is on those contacts. With regard to the question of storage cells, last year I was in the States, and in going across the Union Pacific line I went over mile after mile of automatic signalling, going out West. I am not sure whether it was worked on this principle; it was some sort of track circuit. The rails were certainly bonded, and the signals worked very nicely. I would rather like to know if Mr. Brown can say how they manage to look after the supply there. Do they use portable cells or primary cells, or have they some manner of keeping the secondary cells charged?

Mr. Duddell. Mr. W. DUDDELL: Like the last speaker, I fear that I have no knowledge of railway matters. I can only ask a few questions, and Mr. Gill has largely anticipated the questions I intended to ask. I think if Mr. Brown could give us in his reply some tabulated data as to the resistance of the track between the rails under different conditions of work, and also as to the resistance of the different classes of vehicle when shunting the track, it would be a valuable thing to have on record, so that when we want to calculate track circuits on railways in the future we may know what sort of figures we may expect to obtain. We want to know more or less the average results he has obtained in his extensive practice.

I think a little difficulty has arisen to-night in reading the paper from the terms the author has used. The relay drop failing point and the relay pick-up failing point are not terms that we are quite accustomed to. If Mr. Brown had referred to the volts with which the relay will pick up its armature or drop it, I think I should have read the paper with greater ease. I think the terms Mr. Brown used are terms which are used in another country, and which are not acclimatised in England yet.

One of the speakers has referred to a possible 7-volt drop along the rails. Mr. Brown, in his paper, speaks of 0·2 volt as being the sort of voltage at which his relay operates, and it looks at first sight as if a 7-volt drop along the length of line might make it an impossible thing to work the relay. If I understand him correctly, it is like this:—

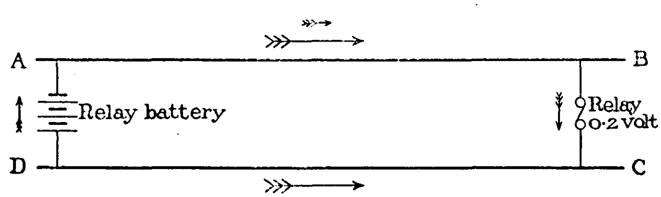

FIG. H.

A B and C D are the two rails, and I assume that there is a considerable difference of potential—say 7 volts—between A and B, and also between D and C. This difference of potential, being due either to extraneous causes or to very large but equal currents in the rails, will be in the same direction in the rail A B as in the rail D C, and I represent these voltages by the long arrows. The small arrows represent the voltages caused by the track battery. If we follow these small arrows round the circuit, we find that the voltage represented by the large arrow is added in one rail and subtracted in the other, so it should not hinder the working of the relay. If this is not the correct explanation, I shall be glad if Mr. Brown will explain, as it is rather difficult to understand how he operates his relay with only 0·2 volt, with possibly some thousands of amperes flowing in the rails. Mr. Duddell.

Mr. THORROWGOOD: May I explain that the 7 volts I referred to were on the extreme end of a tramway line, not a railway line. You get the leaking current from the tramway through the railway line, and back again to the central station of the tramway, not the electric railway. Mr. Thorrowgood.

Mr. DUDDELL: Seven volts on both rails? Mr. Duddell.

Mr. THORROWGOOD: Yes. Mr. Thorrowgood.

Mr. A. H. JOHNSON: I had the honour twenty-three years ago of being connected with some of the first experiments in America on track circuits. Track circuits were first started in this country. One of the first experimenters was Mr. W. R. Sykes, who tried the scheme on the Chatham and Dover Railway in 1870. I believe the first large installation was at the Crystal Palace, about 1876, but, owing to the principles of the thing not being clearly understood, it was a failure, although it is to be noted that Sykes used a one-cell battery and a one-ohm relay in that installation. The Mansell wheel was the difficulty. When we first started in America we had a great many failures through not understanding the principles on which we were working. Although several members have spoken of the paper Mr. Brown has just read as not being very clear, it is the best exposition of the matter that I have ever read. Perhaps Mr. Brown will admit that the margin of 25 milliamperes between the current at which the armature picks up and that at which the armature drops is not ideal, and I think he says so in his paper. That is already being overcome in the alternating track circuit relay, but the last word has not yet been said on the design of direct-current relays. I think it is possible to design a direct-current relay with a very little margin. The armature might be balanced in quite a different way. Instead of having to make a hard contact it might make a mercury contact, and the whole thing might be protected from the weather and moisture by being immersed in a light oil. I have had such a relay made, and I believe you will find that relays will in the future be made on those lines. In conclusion, I think we have to thank Mr. Brown very much for his able paper. Mr. Johnson.

Mr. F. C. RAPHAEL: There is one question I would like to ask. Is it right that the whole system should depend on a $\frac{1}{4}$ in. thickness of fibre between the two lengths of rails, for if this $\frac{1}{4}$ in. gets short-circuited the signal would immediately go to danger and the whole system breaks down. There is another point I would like to ask about Mr. Raphael.

Mr. Raphael. in connection with the insulating joints. Mr. Brown showed us on the screen an illustration of these joints (in which, by the way, the width of fibre certainly looked greater than $\frac{1}{4}$ in.), and subsequently he pointed to the bolts being insulated with bushes; but I do not quite see why, if he uses wooden blocks as fishplates, he wants to insulate the bolts that go through them as well.

Mr. Sayers. Mr. J. SAYERS (*communicated*): I am sorry I cannot be present. I should particularly have liked to have asked Mr. Brown for more definite information as to the means he proposes for making dirty, irregularly used tracks as safe and reliable with track-circuiting apparatus as are ordinarily clean, well-used rails. I presume his remedy is simply to cut up the track into more and more sections, and so gradually get nearer to a short and perfectly insulated pair of rails. I think myself that track-circuiting should be limited to roads which are in practically constant use, and it should never be absolutely relied on for any track which may lie idle for several hours, especially if the track is then liable to receive light engines or similar vehicles which have been standing all night.

There is also the question of sand to consider. Unfortunately, this is mostly used in front of starting signals; consequently when a light engine comes to a stand at a starting signal it is on the very piece of line which is most likely to have a bad conducting film. I have had cases on the Midland Railway of complete insulation of an engine on a track standing in front of a starting signal where a lot of sand had been previously used by a light engine. Light engines are worse in this connection, as there are no train wheels after them to help clear away the insulating layer. I think it is very desirable for some means to be adopted which will render the operation of the relays more independent of weather conditions in order that the maximum rolling shunt-resistance which will operate a given relay shall remain a constant.

In the event of the use of track-circuiting for automatic signalling it is particularly necessary that the track controlling the last signal should overlap the next one by the usual space of about 400 yards. This has not been done in all cases that I have seen, and the absence of this overlap is to my mind a rather serious matter.

Mr. Brown. Mr. H. G. BROWN (*in reply*): To avoid repetition I will deal with the various points brought out by the discussion under their headings, instead of answering the speakers seriatim.

Economy of Power.—The energy required for the operation of a system of automatic signals is used for the production of the " clear or go-ahead " indications. The " danger or stop " indications are obtained by the interruption or withdrawal of the energy producing the " line clear or safety " signals. The armature of a relay and the semaphore arm of a signal go to the danger position, or go to a position that causes a danger signal to be given, by means of the force of gravity. The movement due to gravity must be reliable, and the weight required to obtain reliability depends largely on the design of the apparatus. To enable the system to operate, sufficient power must be applied to raise

Mr. Brown

these weights in a reasonable time. Economy of power may be obtained by decreasing the necessary work, providing the reliability of operation is not sacrificed. A steam railway track circuit can be reliably operated by maintaining a potential of from 0·2 to 0·5 volts between the rails.

On an electric railway both the traction and the signal currents may make joint use of one at least of the track rails. The presence of both currents in the conductors forming the track circuit is a normal condition on a railway using the track as a return, and although abnormal on a system with a return conductor rail, it exists with sufficient frequency to warrant a similar treatment of both systems from the signalling standpoint. It is essential, however, that the signal apparatus must be in a certain manner unresponsive to the traction current, that is, it must be impossible for the traction current to cause a false "section clear" indication.

In the direct-current system obtaining this result, the potential between the rails must be greater than one-half the potential drop within the limits of the track section caused by the traction current. This minimum track circuit potential value is necessary to insure an uninterrupted exhibition of the "line clear" indication when the section is unoccupied.

It is unnecessary and therefore unwise to use more power for a signal system than is required to meet the above conditions.

Storage and Gravity Batteries.—The following are three methods of using batteries for track circuiting: the gravity battery, the portable storage battery, and the permanent storage battery charged from mains run to the battery locations. Which scheme is used depends on the size and importance of the installation and other local conditions. Permanently located storage batteries with a system of charging mains would be cheapest and would give the best results on a four or six track line having short sections and a frequent traffic, while the gravity battery would be a more economical means of obtaining power on a line carrying a relatively small traffic with long distances and requiring a small amount of power per unit of distance. The use of storage batteries is to be preferred in intermediate cases where there may be uncertainty as to which would be cheapest.

The Relay.—The efficiency of the track circuit will be increased by the reduction of the difference in value between the armature pick-up and drop points. This reduction can be obtained by the use of the moving coil relay, although the difference cannot be entirely removed. An application for a patent has been made to cover the use of this type of relay, in connection with a track circuit to obtain the benefits of the principle involved.

The platinum to carbon contacts do not "give freedom from lightning," but prevent the contacts fusing together when subjected to intense extraneous currents.

The back contact pressure of the standard steam railway relay described is approximately 25 grammes.

Mr. Brown. It is universal practice to adjust relays by the milliamperes passing through them. I believe it is better to use a voltmeter in multiple than a milliammeter in series when the relay is in service on a track circuit. The calculations are simpler and the condition of the circuit is more graphically evident. I most heartily join Mr. Sayers in his wish that the operation of the relay could be independent of weather conditions and the value of the effective rolling shunt could be always the same.

Ballast Resistance.—In actual practice the minimum ballast resistance will be found to be from 4 to 12 or 18 ohms per thousand feet. With fang bolt construction in normally wet and poorly drained places it is not unusual to find but 1 or 1½ ohms per thousand feet. There are many long track circuits working satisfactorily for main line traffic that have a total resistance between rails of only one quarter or one half ohm. I have made many ballast resistance tests to find out whether or not the resistance varied with the potential used, but I have never obtained results that led me to believe this was the case. If there is any difference up to, say, 7 or 10 volts, I think it is so small as to be practically of no importance.

Rail Resistance.—The resistance of an 85-lb. rail is approximately 0·01 ohm per thousand feet. The total rail resistance of a track circuit varies. The total resistance of the bonds is usually greater than that of the rail itself, particularly so when short rails are used. The variation is caused by the varying resistance of the rail joints. The total resistance will never be less than that of the rail only, and never as great as the resistance of the rails plus the bonds. The resistance of an unbonded joint may be anything from practically nothing to an ohm or two. I once tested a joint carrying heavy traffic that was tightly bolted up and had a maximum resistance of 15 ohms. Any result from a very low resistance to the maximum mentioned could be obtained by tapping it with a sledge hammer. The better the bonding the better the results.

Insulating Joint and Copper Bonds.—In my experience a copper bond properly installed gives no trouble whatever, due to electrolytic or chemical action. I should think that the case mentioned where a wooden joint pulled apart and the rails separated two inches should be considered a criticism of the permanent way construction or maintenance rather than of the wooden joint.

Sand.—It is evident that there must be a more or less intimate relation between the vehicle and the rails. But it is impossible to say without knowing the exact conditions existing at the time, in the case mentioned by Mr. Sayers, whether or not the difficulties encountered were insurmountable. In my personal experience I have never known a case when these difficulties could not be overcome.

Overlap.—An overlap is absolutely necessary to insure safe working. In no case should it be possible for a signal to go to the safety position until the tail of the train has passed a certain distance beyond the next signal.

The length of this overlap should be determined by the braking rate and maximum speed of the trains. It is usual practice to take the distance required to stop a train travelling at maximum speed by an emergency application of the brakes made when passing the signal, and to add, say, 25 per cent. as a factor of safety. The distance is not always the same at all signals, as it is altered by the alignment and grade. This allowance is amply sufficient, as it is reasonable to assume that the application of the brakes will be made before passing the signal, if at all, unless the automatic stop is in use. If the overlap is short the signal need not go to danger until the front end of the train has reached the release point of the previous section, but if it is long it is better to make the overlap absolute, that is, the signal is put to danger as soon as the front end of the train passes it, causing both signals to be at danger while any part of the train is in the overlap. Mr. Brown.

Extraneous Currents.—The time available is insufficient for an exhaustive treatment of the effects of extraneous currents on the track circuit. It is extremely unlikely that the total return drop of a train system would ever be felt on a single track circuit, though it is often the case that extraneous currents create a potential between the rails of a sufficient value to interfere seriously with the operation of the system. It is evident that this potential need not be very high to accomplish this result, because the normal track potential is less than a volt.

Generally, this interference tends towards the interruption of traffic only, but under certain conditions it may cause the exhibition of falsely clear indications when the section is occupied, unless a system which is safeguarded from the dangerous effects of these influences has been adopted. Such a system should be chosen for localities where trouble may occur from these causes.

The President.

The PRESIDENT: I now ask you formally to convey your thanks to Mr. Brown for his paper, and for giving in his reply some of the additional information asked for in the discussion.

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

The meeting adjourned at 9.40 p.m.