graphs; and would add that this Paper has been written in an endeavour to redeem a promise made to Mr. R. Carpmael, O.B.E., M. Inst. C.E., a short time prior to the outbreak of war.

The Paper is accompanied by six sheets of diagrams and four photographs, from which the Figures in the text, the folding Plates, and the half-tone page Plates have been prepared.

Discussion.

The Author introduced the Paper with the aid of a series of lantern-slides.

Lt.-Col. G. L. Hall observed that one underlying fact which should be remembered was that the men, on both the permanent way side and the signalling side, were becoming much more highly educated and critical, and much more care should be taken than had perhaps been the case in the past to install apparatus that could in fact be maintained in accordance with the standards laid down. That meant that the facing points should be set so that they did not move, and that applied particularly to moving diamonds, which were difficult to maintain unless the road was very tightly anchored; otherwise it was impossible for the signal engineer to keep them going at all.

Soon after he joined the Southern Railway he had found a set of points, not far from London, with a mechanical detector rod 23 feet long, which wobbled about and was not correctly held: any attempt to insist on the maintenance staff keeping the detection adjusted to $\frac{1}{10}$ inch or $\frac{1}{8}$ inch was foolish. A good deal could be said for limiting the length of rod in mechanical detection to something like 6 feet and to insist on the mechanical detectors being on extended timbers. If that was impossible it would probably be better to adopt electrical detection.

Track circuiting was the bugbear of the civil engineer, because it cramped his style in many ways. The Author had dismissed steel sleepers quite rightly by saying they were impracticable for track circuits, but nevertheless inventors still produced beautifully drawn diagrams of insulation between the steel sleeper and the rail. Imagination boggled at the idea of a track circuit having 4,000 potential points of failure per mile.

The question of through bolts was a bone of contention at the moment. The Author had pointed out that the leakage from rail to rail when through bolts were used was twice that which occurred when screwed fastenings were employed, and that fact increased the difficulty arising from the wide variation between wet and dry conditions.

In dealing with multi-aspect colour-light signalling the Author had brought out a point which was very often not appreciated, namely, the relation between the number of aspects and the braking-distance That was the essence of the whole matter. The number of aspects was governed by headway and braking distance.

Other important factors in the relation between the permanent way side and the signalling side were block joints, which were always troublesome and necessitated a very high standard of permanent way maintenance at the joints. Further the permanent way staff could help considerably in clearing obstruction of points. Many permanent way men did not appreciate the importance of seeing that even the smallest obstruction was cleared away. He had had a number of failures due to one thickness of cigarette carton which had become jammed in the points. A certain amount of trouble on his line had also been due to the use of steel tape on the track. It was impossible to avoid its use altogether, but the permanent way staff should use their discretion and should realize the harm that could be done by short-circuiting a track circuit with steel tape. Track-circuit bond wire was another point of contact between the civil engineer and the signal engineer. A modification of the present type of bond wire was being considered, which would be less of a nuisance to the permanent way and less easily damaged.

He believed that for many years to come straightforward, old-fashioned, two-aspect mechanical signalling would be the primary standard. Multiple aspect colour-light signalling, and the various other devices, were very useful in their place, but they could very easily be overdone, and for ordinary high-speed running with moderate headway there was no reason —and, as far as he could see, there was not likely to be for some time—to depart from two-aspect mechanical signalling.

Mr. H. A. Alexander observed that he had been interested in the Author's reference to the time-interval. It had been found in 1928 that the Americans still adhered to the old custom, and the guard of a passenger train lighted a fusee at the rear of his train before he gave " Right away ", so that the driver of the engine coming behind him would know that there was something 5 minutes or less ahead.

He hoped that colour-light distant signals would be increased in number. They did not completely eliminate fogging, because it was still necessary to provide a groundsman at the box, but they did assist in saving man power and they reduced the time expended in making up pay-sheets.

He regarded with alarm the Author's statement that curved switch tongues assumed a vertical curve and in consequence bore only upon the heel and front slide chairs. If such a condition arose it was due, in his opinion, to one of two causes; namely, bad manufacture or bad maintenance. Recently he had had a special examination made of more than 400 pairs of curved switch tongues and had found that in only six cases did the switches not rest on all the slide chairs.

He had also been very intimately concerned with track circuiting. An additional signal had been placed on each road in the Severn tunnel about 2 or 3 years ago, and it had been associated with track circuiting. As a result the civil engineer had had to pull out his perfectly good Great Western through bolted sleepers and put in three-hole coach-screwed

sleepers, because the Author had stated that the loss in ohms was so great that it was worth the Company's while to carry out that re-laying long before it was due. Moreover, the addition of signals was a serious matter from the maintenance engineer's point of view, especially in such places as the Severn tunnel. It was true that more trains could now go through the tunnel—that was the object of installing the additional signals—but the drivers were much more cautious in approaching the additional signals; they used much more sand on the downhill gradient and, having confirmed that the signal was right, they proceeded to the bottom of the tunnel with insufficient speed or power to ascend the 1 in 90 gradient, so the engines were coughing their hearts out and not only wearing the track but also damaging the ballast.

The Author had mentioned the additional number of cuts in rails in fittings where there was track circuiting. From the civil engineer's point of view, cutting was a very serious and lengthy job. He was aware that there were some points at which the cuts were necessary and which could be determined only on the ground. A considerable number, however, could be predetermined from the diagram, and he suggested that co-operation between the civil engineering department and the signal engineering department while the fitting was being constructed in the crossing workshop, would result in a saving of much time and labour on the ground.

One problem in railway working which did not yet seem to have been satisfactorily solved was to caution a driver proceeding along a loop or relief line who inadvertently mistook his signal. Several such cases had occurred recently; the result was that the excellent catch-points installed by the civil engineer shot the driver off the road. Had the Author considered the installation of dead automatic train-control ramps on such loops, so that it would be practically impossible for a driver to proceed with the mistaken running? Further, had the Author considered the provision of portable A.T.C. ramps which could be used in connexion with re-laying, with the idea of eventually reducing to nil the man time now utilized in flagging?

He agreed that leakage through cracks in concrete sleepers which had not been waterproofed was a natural consequence of the material, but he could not follow the Author's remark regarding the waterproofing of the aggregate.

Mr. A. E. Tattersall observed that the Author's statement, that in many cases it was desirable to operate the distant signal electrically, was quite true, but why not adopt the colour-light system and secure the great advantage of being able to dispense with fogging?

The Great Western Railway was to be congratulated upon its pioneer work in automatic train control and upon the results achieved. The system was designed to meet the distant signal in a two-aspect system only, and there did not appear to be any practicable method of adapting it to a multiple-aspect system. He considered that people who favoured the present method of two-aspect train control were really not consistent. In

two-aspect semaphore signalling, where a distant signal was erected under a stop signal, in order to make for safety and ensure the proper working of the system fogmen had to be retained.

The subject of automatic train control was a very thorny one and agreement was unlikely to be reached for some time. Some thought that the extension of colour-light signalling would render automatic train control unnecessary. On the other hand, if something additional was necessary, his view was that the signals should be reproduced in the engine cab (continuous cab signalling), with brake control, as found necessary, when the question of fitting all trains with continuous brakes had been decided. He considered that it was essential that that question should be decided before any progress was made with the automatic train control system.

With regard to the fogging of distant signals, his opinion was that the colour-light system should be used for distant signals, and he suggested that the civil engineer could be placated by replacing semaphores by colour-light signals as opportunity offered. On the London and North Eastern Railway and, he believed, also on the London, Midland and Scottish Railway, the practice for some years had been that in the case of all new works and renewals semaphore signals were replaced by colour-lights, in order to dispense with fogmen.

The lock and block system of signalling had served a very good purpose, but with the interlinking of the block with the home and starting signals, together with the proving of the remaining signals and the necessary track-circuiting, a much better system was afforded, with none of its disadvantages.

In dealing with the track circuit, the Author had mentioned the question of minimum train shunt value. Mr. Tattersall thought that the time had arrived for a more logical treatment of that subject. To speak of a value of 0·5 ohm without reference to the impressed rail voltage was meaningless. In many cases the shunt resistance of an axle was not linear, that was to say, it was not ohmic resistance, and if it was likely to approach a value of 0·5 ohm the bulk of it might be considered film resistance, which was very susceptible to the applied rail voltage. Taking the case of two track circuits, in one of which the rail voltage was 0·5 and in the other between 2 and 4, it might be that the minimum shunt given by the first was 0·5, whereas that given by the second was considerably less; but the second was a much safer circuit, owing to the fact that the higher rail voltage would eliminate the film resistance. In many cases the value of 0·5 could not be obtained, and it was not necessary, provided the circuit was suitably arranged. Did the Author insulate the through fastening from the chair, where such fastening was employed ?

The compressed laminated wood type of insulated joint had answered very well from the track-circuiting point of view, but he would like to have the opinions and experience of civil engineers on that type of joint from the track point of view.

With reference to steel sleepers, experiments were being carried out to see whether there was any alternative to the track circuit. It was too early yet to express an opinion, but the results to date were such as to convince him that the subject was worth pursuing.

The use of the hand generator was a very convenient method for operating power points, but where it involved an increase in the classification of the signal box he thought it would be better to use battery operation, which would certainly be cheaper ; at least, that was the experience on the London and North Eastern Railway.

With regard to mechanical detection on power points, had the Author had any cases in which the signalman had been able by straining the wire to operate the signal lever ? Power points were generally at some distance from the signal-box, and Mr. Tattersall knew of cases which had occurred. The signal had not cleared, but the pulling of the lever had released the distant signal, with serious results in one recent case.

He could not see any need for a fifth aspect, provided the double yellow meant " Pass next signal at restricted speed ", as it did on the London and North Eastern Railway. He knew of no reason why that aspect should not be repeated as necessary, and much could be done by the approach control of aspects in densely signalled territory. With the yellow-green aspect, should the yellow light fail it would be neceesary to provide special arrangements to prevent the green being shown alone, which would not be very desirable.

The Author had referred to braking distance in terms of express and medium-speed trains. Mr. Tattersall considered, however, that the train which required consideration was the heavy unbraked goods train. A comparison of brake-power rather than speed was desirable.

Track-circuiting of single lines had been the practice of the London and North Eastern Railway for many years, and the method adopted was very similar to that described by the Author, except that the working of the interlocking levers was just the reverse—the signalman in the accepting box pulled the interlocking lever. That method presented many advantages.

More development was taking place at present in signalling and communications than in any previous period, and signalling development was very closely related to operating requirements. By a turn of the wheel of development, many of the present ideas might have to be cast aside, and such a turn might occur in the immediate post-war years, when the railway companies would have to fight harder than ever to keep their place in the transportation world, owing to the development of aerial and other forms of transport.

Although railway signalling was often referred to as a science, it was by no means an exact science. Much of the development in signalling during recent years had been due to development in other branches of engineering, such as mechanical engineering, electrical engineering, communications,

electronics, and physical research. The young engineer should watch the progress made in all such directions, in order to see whether any of the noteworthy developments could profitably be used in railway signalling, and, if he was assured that a case could be made for so doing, he should pursue the matter further. He would encounter objection and prejudice, owing to the natural conservatism of railway men, but that should not deter him from doing his duty, and, if he persisted, he would win through.

Mr. W. K. Wallace observed that some time ago he had carried out a series of tests on the London, Midland and Scottish Railway with through-bolted road, and, in order to ensure that the through-bolted track was properly assembled, he had asked Mr. R. Carpmael, M. Inst. C.E., then the Chief Engineer of the Great Western Railway, to chair the sleepers for him. He had found that that track stood up to sharp curves better than did screwed track. On the other hand, the signal engineer had told him such a lugubrious tale that he had hesitated to go on with it. That raised the very important point of the degree of control of permanent way design to be enforced on the civil engineer by the requirements of the signal engineer, particularly in track circuiting. The signal engineer had ruled out steel sleepers and wished to rule out concrete sleepers, except at places where he did not want a track circuit—which appeared to be very few nowadays. But if the civil engineer could obtain good timber sleepers at an economic price he would be quite willing to give up some of the substitutes that had been inflicted upon him during the war.

Generally speaking, he thought there was still room for more co-operation between the two departments, apart from the question of drains, and he particularly liked Mr. Alexander's suggestion that there should be co-operation between them while the fittings were being made in the workshop. The block joints could be located and formed before work came to be done on the ground.

He would like to know the Author's opinion of the laminated fishplate, and also whether a more satisfactory block joint than the present type could be obtained.

Major R. F. Morkill agreed with the Author that a strong case could be made for independent responsibility on the part of signal engineers on large and complex systems. That was borne out by some of the large American railway organizations.

The Author had very rightly stressed the importance of distant signals, and it was essential that drivers approaching them should have as uninterrupted a view as possible. The present practice of replacing the semaphore type with that of the colour light should be proceeded with as quickly as possible. The application of automatic train control was a further convenience for the driver, as well as enhancing safety. Cab signals were preferable to automatic train control because they necessitated greater vigilance on the part of the driver.

Coded track circuiting helped to eliminate some of the depressing

conditions which beset the engineer and his maintenance staff, particularly the top tough skin on the head of the rail. Sleepers with through fastenings were a potential source of trouble unless the track was perfectly ballasted and drained.

Wheel counters operated by mechanical treadles were not reliable for speeds exceeding 45 miles per hour, and, moreover, the treadles required heavy maintenance. An inductive type was, however, being developed, and was actually under test, which it was hoped would correctly record speeds of about 100 miles per hour.

Major Morkill believed satisfactory concrete sleepers could be made, which should permit of reliable track circuiting.

Colour-light signals to meet daylight conditions appeared to be too intensive at night, and it would seem desirable, therefore, to continue the black-out control in a modified form in order to reduce glare, except during fogs or snowstorms.

Single lines were being operated to an ever increasing extent by centralized traffic control in the United States, and some installations extended over a distance of 100 miles from one centre. Similar systems were also in service in the Dominion of Canada and other Dominions. Why not in Great Britain ?

Radio might play a very important part in railway communications, and it was being rapidly adapted to that purpose in the United States, whilst in Great Britain it was being given some consideration.

Mr. G. H. Crook observed that the object of the Paper appeared to be to establish and discuss points of contact between civil engineers and signal engineers ; but, to his mind, those points of contact commenced before the physical field was entered, and concerned the lay-out of points, junctions, stations, etc. It was not perhaps always realized that the signalling scheme was in a very large measure simply a reflector of the permanent way lay-out. In connexion with that lay-out, the question of the space for signals often arose, and the signal engineer should have sympathy with the civil engineer, because many of the difficulties of cramped lay-outs were legacies of the past. The civil engineer's conception of a lay-out did not always produce the best result when analysed from the signalling and interlocking point of view. An Indian signal engineer had expressed the view that all lay-outs should be designed by signal engineers. Mr. Crook was not prepared to endorse that view, but would rather say that it was a matter for co-operation between the responsible departments. The needs of the traffic department had to be met ; the civil engineer had to provide and maintain the lay-out, and the signal engineer endeavoured to erect some respectable looking signals to suit. On the Great Western Railway excellent co-operation had always existed in that respect, and the civil engineer had always been very accommodating and amenable to suggestions.

There were many points of contact in the physical equipment, and the

track circuiting might be said to represent almost a continuous type of contact. In carrying out the general style of track bonding, the bonds were placed about 2 feet from the rail joint on each side, so that there was a gap of about 4 feet in the rail which was not currented by the track circuit and hence was not protected against rail breakages by the track circuit current. He had often wondered why the American type of bond, which was a very short bond fixed into the bullhead of the rail by means of a 3/8-inch pin, had not been adopted in Great Britain, as it enabled practically the entire length of the rail to be protected. It might be that there was some prejudice on the part of permanent way engineers against drilling the bullhead. The Great Western Railway had had one of the American bonds in use experimentally at Reading for a year, but unfortunately the rails had had to be taken out, so that the conclusive result of the trial was lost. So far as it went, however, it was perfectly satisfactory.

There were other points of contact in regard to bridges, viaducts, and so on, which might be built to the various aesthetic designs of the engineer, but to which the signal engineer wished to make various kinds of signal attachments. In some cases he wanted to festoon the structure with cables, perhaps of not quite such a dignified appearance. Such matters, however, were all subjects for accommodation.

Probably the most frequent and contentious point of contact between the two engineers was the switch-point, to which the signal engineer had to make connexions for operating, locking, and detecting. It might have been expected that many of the old-time problems would disappear with the introduction of the flexible stretchers which were now becoming general practice; but flexibility of movement and rigidity of coupling could be truly maintained only if the stretchers were kept firmly bolted to the switches, and he was afraid that that condition did not always obtain. Alternatively the stretchers could be riveted to the switches, but in the event of replacements that might cause considerable inconvenience. In spite of all the improved designs, the old precept that the price of safety was eternal vigilance was still true.

The Author had dealt with manual block in connexion with mechanical signalling and so-called multiple-aspect signalling: but civil engineers might wonder what were the reasons for so much variation and elaboration in signalling systems. The multiple-aspect systems might be said to be the outcome of automatic signal operation by track circuit control. It might be asked why signal engineers sometimes used manual block signalling and sometimes automatic signalling. The answer was largely, though not exclusively, one of economics. For instance, in the case of signalling a service of trains every 80 seconds, such as occurred on the London Underground Railways, it would be very difficult to imagine a signalman going through block instrument and lever movements on two lines for such a succession of trains. Therefore it might be said that continuous track circuit was a pre-requisite of automatic signalling, and that became a

very considerable element of the cost of the signalling. On the Great Western Railway about 18 or 20 years ago frequent proposals were made for automatic or semi-automatic signalling of numerous sections, and the signal engineers were asked for their views upon the economic position in those cases. As a kind of short-cut, they made a series of basic calculations for the cost per annum of manual block signalling for one, two, and three shift-boxes for various sections, and similar calculations for the automatic signalling system. The financial results were plotted to show cost against sectional length, and it was found that the automatic graphs balanced the manual graphs for one, two, and three shifts at approximately $1\frac{1}{2}$ mile, $3\frac{1}{2}$ miles, and $6\frac{1}{2}$ miles of double track. From those graphs it was possible to see by inspection whether in general the cost was an economic proposition or not; but the results were only suggestive or indicative and each case required to be calculated on its individual merits.

Those economic comparisons could be carried further by calculating the cost per annum of signalling a unit length of line for a given headway, or a certain number of trains per hour. An interesting point in that comparison was the very sharp rise in the cost as the density increased. Some of the cases indicated that the cost of the manual system rose at a rate approximately as the square of the number of trains per hour, but the automatic characteristic was of the order of 0·5; in other words, the curve was much flatter. Possibly that explained vaguely why the automatic system was cheaper for high traffic-densities. That subject was no innovation; the Institution of Railway Signal Engineers had dealt fairly fully with it in 1927.

Mr. Crook wished to associate himself with the last paragraph of the Paper and to endorse thoroughly the Author's opinion and prophecy. How far the signalling systems could be further elaborated appeared to depend upon the part that the railways would have to play in meeting the comprehensive needs of the nation, and upon the character and volume of the traffic which they would be required to carry.

Mr. A. Moss observed that it would be generally agreed that railway signalling was a specialized job. It was not easy to obtain a grasp of the true principles of the subject, but the Author had enunciated those principles admirably, and by study of the Paper in conjunction with the two very excellent Papers to which the Author had referred,[1] their task could be considerably simplified. A third Paper[2]—a classic—which was read by the late Mr. R. C. Rapier, Assoc. Inst. C.E., before The Institution seventy-one years ago, contained all the history and background of railway signalling from its inception.

The Author had referred to the distance at which mechanically operated points could be worked. Special dispensations could be obtained to exceed

[1] References 1 and 2, p. 4, *ante*.

[2] "On the Fixed Signals of Railways." Min. Proc. Instn Civ. Engrs, vol. xxxviii (Session 1873–74, Part II), p. 142.

the limit laid down in the Ministry of War Transport's requirements and, Mr. Moss had worked points up to a distance of 446 yards from a signal cabin.

The distant signal was a very important signal. Repetition of the distant lights was not at present a Ministry of Transport requirement, but no doubt it would be made so. In cases where no electric repeating of the lights was provided, the signalman was dependent upon observation and the correct operation of the back-spec ; the latter was a very important piece of apparatus, because a signalman could very easily be led astray by it, with dire results. Interlocking the distant signal with the block telegraph was not new. The Great Western Railway Company had been a pioneer in that respect, for, as Mr. Rapier had mentioned in his Paper, it had been used by that Company seventy years ago. Its great advantage was that it avoided any argument that might arise as to the distant arm hanging off, which in the past had been a constant source of difficulty between the locomotive running department and the signal department, both of which were involved.

It might be of interest to many members to know why the automatic train control ramp was fixed just inside the signal, and not on the approach side when the distant arm was fixed under the stop arm.

Ever since the advent of railways, facing points had been suspect, and that accounted for an elaborate arrangement to safeguard operation. Too much emphasis could not be placed on the necessity for frequent inspection in order to maintain the fine clearances allowed for the detection and plunger locking.

Mr. Moss agreed with the Author on the advantages of colour-light signals. There was a possibility of fixing those signals at ground-level and so obviating the need for the expensive and cumbersome gantries which were necessary in certain locations owing to the space being insufficient for an elevated signal to be installed.

Much had been said about track circuiting in the course of the discussion. Mr. Moss was sure that any civil engineer who had to maintain track would be careful to see that his men did not tip ballast on the signal wire and lay out the rails so as to cut out the insulated joints.

He agreed that it would be many years before the simple mechanical installation was eliminated. That type of installation, in conjunction with the many electrical aids now available, would probably survive for a much longer time than anyone present at that meeting.

Mr. A. W. Woodbridge observed that he proposed to confine his remarks to the permanent way. He considered that in many cases the assembly of the switches on the ground left much to be desired. The problem arose of matching up the detection at $\frac{1}{8}$ inch, and the slightest error in fitting the points would throw that right out, causing the mechanical detector slides to bind or even foul. Strangely enough, the result was usually known as a signal failure.

The first and third of the functions of signalling, as stated in the Paper, covered most of the attributes of the usual two-aspect signalling. Traffic movement was facilitated by two-aspect signalling, but multi-aspect signalling was the modern method. In many cases the application of multi-aspect signalling obviated the necessity for some very heavy civil engineering works.

Mr. Woodbridge would like to see developed a steel rail which would not form a high-resistance film, because he thought that, whatever the voltage on the track, that would never be entirely overcome by electrical means. He would also like to see a non-rusting and a non-skidding rail.

He hoped that in all new works the signal engineer would be considered and afforded ample room for cables, wires, and other fittings, so that he would not have to make shift in the future as he had so often had to do in the past.

Mr. E. G. Brentnall observed that in the past many railway engineering schemes could have been simplified, and probably cheapened, if the question of signalling had been considered from the earliest stages. All too often the signal engineer had been confronted with a *fait accompli* with regard to lay-out and had had to do the best he could in the circumstances, with less efficient results than might otherwise have been obtained.

Reference had been made in the discussion to the question of facing points and clearances of $\frac{1}{8}$ inch, which were very important. Sometimes the permanent way staff, who were used to dealing with 60-foot or 90-foot rails, did not appreciate the value of $\frac{1}{8}$ inch. The trouble was that, if any slight slackening of the gauge occurred, a resultant failure was regarded as a signalling failure.

Good drainage of the ballast for track circuits was essential, and that was particularly true in tunnels, where, whilst the ballast might be perfect from a permanent way point of view, owing to deposits of films of wet soot from the smoke it was not so good from the track-circuiting point of view and consequently difficulties in working occurred.

If through fastenings were employed for sleepers track circuits could be made to function satisfactorily, but they would have to be shorter in length.

Cutting rails to give block joints opposite each other in points and crossing lay-outs was admittedly a nuisance from the civil engineer's point of view, but dead sections were equally a nuisance from the signal engineer's point of view.

The Author's remarks on multi-aspect signalling were very clear and demonstrated the advantages of that system. If Fig. 1, Plate 1 and Fig. 9, Plate 2 were compared, it would be seen that with the semaphore signalling in Fig. 1 three trains could occupy the section shown, the signals being operated from three signal-boxes, where as in Fig. 9 seven trains could occupy the same space, all the signals being operated from one signal-box.

With regard to the double yellow aspect approaching junctions on the London and North Eastern Railway, the Author's remarks applied where there was a connexion laid in for speeds of up to 30 miles per hour, and Mr. Brentnall thought one point for civil engineers to consider in schemes was that where possible the connexions to and from the routes should be laid out for reasonably fast running; otherwise the full advantages were not gained.

The double yellow had also been used on the London and North Eastern Railway for high-speed trains which were of special stock and required a long distance in which to brake from high speeds. The additional distant signal provided for a high-speed train showed double yellow or green and worked with the ordinary distant signal.

The post-war schemes to which reference had been made would offer a wide field for the application of modern signalling practices; and, although two-aspect block signalling would survive for a long time, it could be confidently expected that modern principles, if applied judiciously, would supply their own economies, directly or indirectly, in traffic facilities.

*** **Mr. R. L. McIlmoyle** observed that in an effort to be all embracing, the Paper was not so useful as it otherwise might have been for the purpose suggested by the Author.

The Author had concluded that manual block signalling was likely to be a dominant factor in traffic operation for many years to come, and Colonel Hall had confirmed this view. Mr. McIlmoyle's own experience had covered all the types of signalling mentioned in the Paper, with the exception of four-aspect and five-aspect and automatic train control and he also could confirm that the greater part of the work was concerned with the ordinary manual block type of signalling. In view of its importance, space allotted to it was definitely inadequate. The Paper would have been much more useful if more information had been given with regard to the installation and maintenance of that type of signalling, in which the average railway civil engineer was likely to be short of actual experience.

Fig. 2, Plate 3, showed the lay-out of a pair of facing points and although the locking bar was clearly indicated, Mr. McIlmoyle had been unable to trace any mention of it, its function, adjustment, or necessity, in the Paper; neither was any reference made to the various types of mechanical lock which were available, or to their use in different circumstances.

It was doubtful whether the lock and block system was justified in many cases where it was installed. He had known of cases where the signalling had operated satisfactorily and safely for years without the signals being locked with the block instruments and the addition of the necessary equipment including the treadle, to enable that to be installed

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*** This contribution was received in writing.—SEC. INST. C.E.

could hardly be justified when traffic was light and maintenance staff was not readily available.

The Author considered that track circuits could not be satisfactorily employed with concrete sleepers, nor easily maintained where through bolt fastenings were used for the chairs. As a civil engineer, Mr. McIlmoyle was not worried by trifles such as those, and had installed a considerable section of automatic signalling over track where there were several stretches of concrete sleepers, many of which had reached the stage where they were badly cracked; but no difficulty was experienced in maintaining the track circuits. Moreover in both that and other cases where track circuits were installed, the chairs were fastened by through bolts, and again no difficulty was experienced with regard to keeping the track circuits up, except in one particular circumstance where the sleepers for a short time were on ashes rather than normal stone ballast. As soon, however, as stone ballast was provided the track circuit picked up; and although that was over 15 years ago, so far as he was aware no further trouble had been experienced.

It was possible to lay complicated trackwork with track circuits without cutting joints on the site, the location of track circuit cuts being determined beforehand and provided for in the pre-assembly of the points and crossings.

Power operation of remotely situated points by hand-generator, was a useful solution to some problems, but its use could be overdone and in some cases it was employed without any reasonable return on the expenditure. With the prospect of power-supply being readily available at many points in Great Britain in the immediate post-war years, the use of that type of point operation, namely hand-generator, would cease to be attractive.

It might have been of interest to mention, when referring to single lines, that tablets or tokens could be interchanged between the signal staff and the engine driver by mechanical means, thus permitting through running.

When discussing power signalling installations, the Author made no mention of the use of the ordinary lever type frame with mechanical and/or electrical interlocking combined with hand or power operated switches. That method had been adopted and proved entirely satisfactory in cases where the more elaborate systems, such as those described, would have been unjustified.

Mr. McIlmoyle considered it would also have been of some assistance to the railway engineer unacquainted with signal work, if some reference had been made to the by no means numerous, but, in general, excellent text-books which covered both mechanical and electrical signalling, which were available in Great Britain.

The Author, in reply, expressed his appreciation of the manner in which his Paper had been received; the observations made had been more

in amplification of the Paper and would be of considerable help in amplifying his own statements.

Colonel Hall was responsible for a railway which had probably more successful multi-aspect signalling than any other railway in the Empire, and his observations were therefore of particular value. But he could not agree with Colonel Hall upon one point in regard to detection. He would not mind having a 25-foot connexion from the switches to the detection, because with the anchored base-plate, which provided for any contraction and expansion caused by variations in temperature, it was quite easy to maintain an adjustment of $\frac{1}{8}$ inch. It was possible, however, that on the Southern Railway a finer limit was maintained; in fact, he believed it was $\frac{1}{16}$ inch.

In reply to Mr. Alexander, the Great Western Railway, having adopted automatic train control, could dispense with fogging, but for the necessity of providing for foreign engines running over the Great Western Railway's lines.

He assumed that Mr. Alexander's remarks about switch tongues did not refer to the rigid heel type and he illustrated by means of a sheet of paper the physical impossibility of a curved and canted tongue lying flat in the horizontal plane.

Something had to be done to prevent leakage of water through the mass of the concrete, and it was for the manufacturers, in conjunction with the civil engineers, to provide some method of waterproofing the aggregate.

Co-operation between the civil engineering department and the signal engineering department in the matter of fittings in the shop, already existed on the Great Western Railway, the civil engineering department being supplied with a diagram showing all the cuts as far as possible.

All departments on the Great Western Railway had given a great deal of thought to the problem of drivers mistaking the main line for the loop, but no solution had yet been found. The Author considered that drivers should know the signals, and that there was really no excuse for them making that mistake.

Many people had suggested the use of a ramp for the above-named contingency and for permanent way alterations, but on the Great Western Railway the ramp was used, in principle, for one purpose only, namely, as an indication for the distant signal, and its signification would be prejudiced seriously if used for any other purpose. He did not think that any permanent way man working on the line would care to let his life depend upon the operation of a ramp, as if it failed to operate the man would have no protection whatever.

With regard to Mr. Tattersall's suggestion that colour-light signalling should be adopted rather than working the distant signal electrically, the Great Western Railway had automatic train control and there was no real necessity for the colour-light signal. It was partly a question of expense. The Company had not yet adopted the wholesale provision of motor

operation for distant signals. If and when it did, it would certainly consider colour-light signals also.

He did not understand Mr. Tattersall's difficulty with regard to automatic train control and the red light, because automatic train control could be used with three-aspect signalling and was actually being so used to-day.

No insulation was provided between the through fastening and the chair in Great Western track circuits.

With mechanical detection on power points it was possible for the signalman by straining the wire to operate the signal lever. The pulling of the distant signal lever, however, would not lower that signal as, owing to its great distance from the signal box, it was worked electrically and controlled by a contact on the arm of the home signal.

The Author agreed with Mr. Tattersall that braking distance was a question of brake power rather than speed, and the effect of fitting all types of freight stock with brakes would have an important influence on signalling.

Any increase in the classification of the signal-box through the use of the hand generator for operating power points (he knew of only one case where that had occurred), would be outweighed by the expense of maintaining batteries for operating the motors. He considered that the use of the hand generator was the best and most convenient method; it would be better to adopt it even if a little increase in the classification were involved.

In reply to Mr. Wallace, drains, after all, were the Civil Engineer's job and from the track circuiting point of view the more drains the better.

The advantage of through bolts in the track was appreciated, but the effect was to double, approximately, the leakage of current from rail to rail and, to reduce the length per unit track circuit.

The track circuit was not designed to create difficulties in permanent way design but to achieve greater safety, increase traffic facilities, and effect economies, and it was those considerations which were the essential reason for the large scale expansion of track circuiting to-day.

From a track circuit point of view the laminated fishplate was a great advance upon other types and the Author knew of none other more satisfactory.

Major Morkill had expressed his preference for cab signalling rather than train control. It should be pointed out, however, that the former system diverted much of the driver's attention from a continuous look out of the cab.

A very large number of treadles were used on the Great Western Railway and no difficulty was experienced with them. He would like to hear from the civil engineers how a treadle could be worked on a flat-bottomed rail.

The dimming of lights at night was under consideration at the moment.

On the Great Western Railway it was found that drivers preferred the colour-lights to be up to full strength at night.

Centralized traffic control was peculiarly suitable to large areas in America; the British railway system was the most intensive in the world, with more junctions in relation to route mileage than any other country. Therefore the system did not offer the same savings in, or solving of problems of man power in out of the way places, in Britain. The subject, however, was receiving consideration in Great Britain.

So far as lay-outs were concerned, co-operation between the civil engineering department and the signal engineering department already existed. He endorsed Mr. Crook's remarks about the help which the Chief Engineer of the Great Western Railway gave to the signal engineers on all works which the two departments had to carry out in co-operation.

Mr. Crook's remarks, like those of Colonel Hall and Mr. Tattersall, had added a valuable contribution to the Paper. A large percentage of track circuit failures were due to breakage of bonds and there was a great deal to be said for the American bond mentioned by Mr. Crook; the Author considered that it should be given an extended trial in Great Britain.

Mr. Moss had referred to long-distance mechanical working of points; the Great Western Railway had worked up to the same distance mentioned by him, but the Author would not recommend doing so for facing points with the standard rigid heel type of switches.

When the distant arm was fixed under the stop arm, the automatic train control ramp was fixed immediately *ahead* of the signal. That permitted the driver getting an automatic train control signal after having been brought to a stand at the stop signal.

Mr. Woodbridge had brought out a noteworthy point in connexion with permanent way fittings and their relation to signal failures. Actually the purpose of detection was to prove the correct position of the switch tongues and a so-called failure of the detection was an indication, not of a signal failure, but of a permanent way failure.

That point was also mentioned by Mr. Brentnall in making reference to a feature of primary importance, namely, slackening of the gauge.

The Author would remind Mr. McIlmoyle that, as he had stated at the commencement of the Paper, the intention was to deal with principles rather than with details of practice; to have done both would have made the Paper inordinately long. It was assumed, and reasonably so, that railway civil engineers were well acquainted with mechanical facing-point gear. Reference was made to Mr. Blackall's Paper of 1911 [1], which dealt particularly with mechanical details in signalling practice.

It was common knowledge that considerable areas of the British railways were operated safely without lock and block; the fact remained, however, that it was a valuable addition as a safeguard and its equivalent

[1] Min. Proc. Instn Civ. Engrs, vol. clxxxv (1910–11, Part III), p. 153.

was an adjunct of track circuit and interlinking of signals in manual block signalling.

Mr. McIlmoyle had said that as a civil engineer he was not worried about such trifles as concrete sleepers and through bolt fastenings. If he were a signal engineer responsible for thousands of track circuits working under all kinds of physical and traffic conditions as met with on the main line railways of Great Britain and, if he were acquainted with the operating figures of the tests carried out on concrete sleepered track by the main line Railway Companies during the last twelve months, he would find that he would have to take a less complacent view, at least so far as the problem of concrete sleepers was concerned. With regard to through bolted road, as the Author had stated in his Paper, the Great Western Railway worked their track circuits with that type of permanent way satisfactorily; the fact remained, however, that the leakage from rail to rail was twice as great as in the case of screwed fastenings and that standard of ballasting and drainage had to be correspondingly high.

Where operating conditions permitted, the hand generator method for working remotely situated points was, in the Author's opinion the best, whether or not a power-supply was available. It was cheaper in first cost and, by eliminating batteries, reduced the cost of maintenance also.

The Author had omitted reference to token exchanging by mechanical means as it was an infrequent method and not comparable with lock and block or electric interlocking with track circuit.

The use of the ordinary lever frame for operating power operated switches in power signalling installation was only an extension of that adopted for remotely situated points at mechanical signal boxes and was dealt with in that section of the Paper.

There was no up-to-date text book, so far as the Author was aware, dealing with principles of signalling as a whole, but there were several dealing with different branches of mechanical or electrical practice. The most comprehensive was "Railway Signalling and Communications" published by The St. Margaret's Technical Press, Limited, which the Author could confidently recommend to Mr. McIlmoyle or any other civil engineer wishing to pursue the subject.

RAILWAY SIGNALLING FOR THE CIVIL ENGINEER

FIG. 1

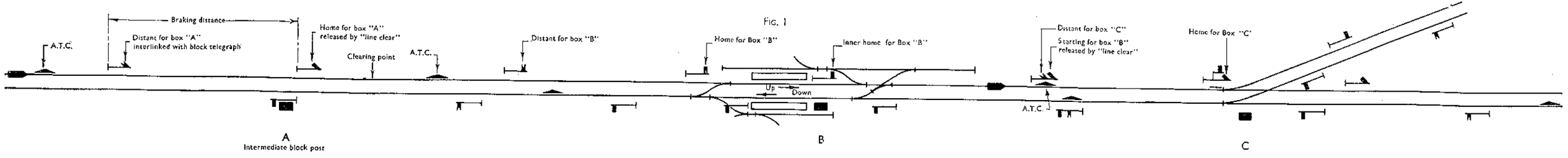

FIG. 5

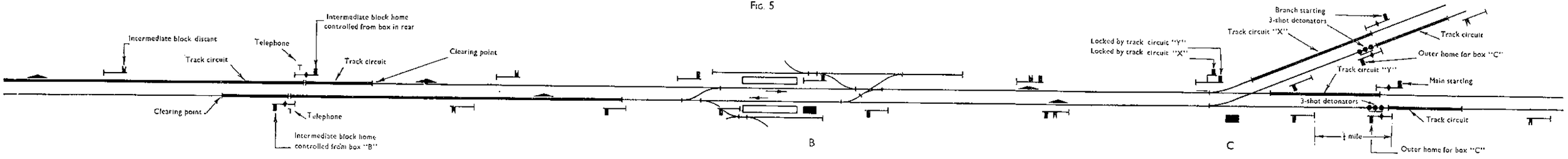

FIG 6

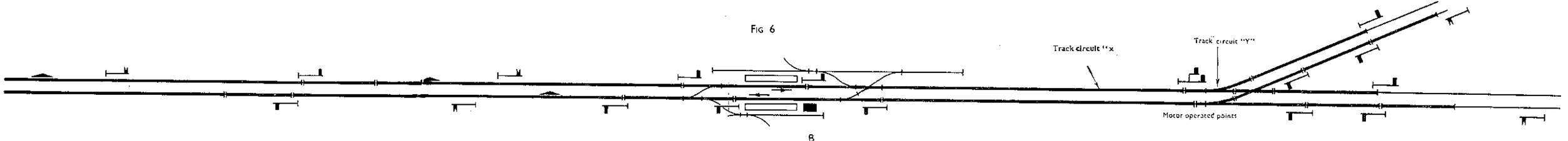

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FIG. 9

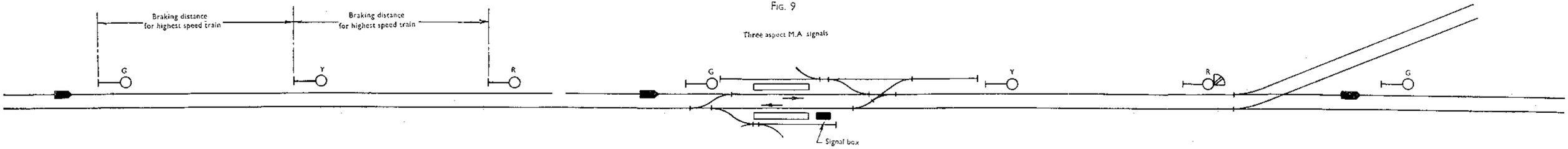


FIG. 11

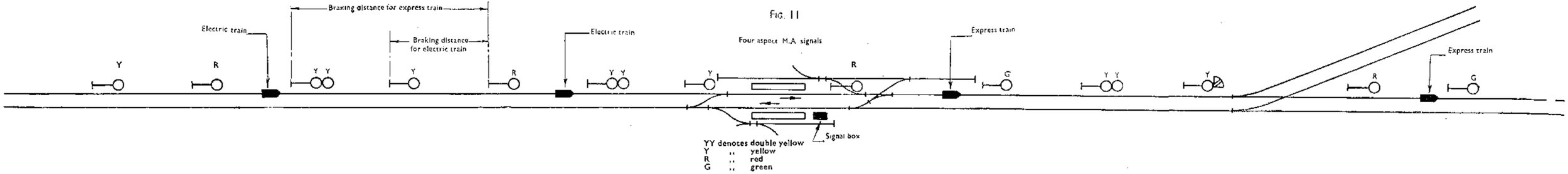
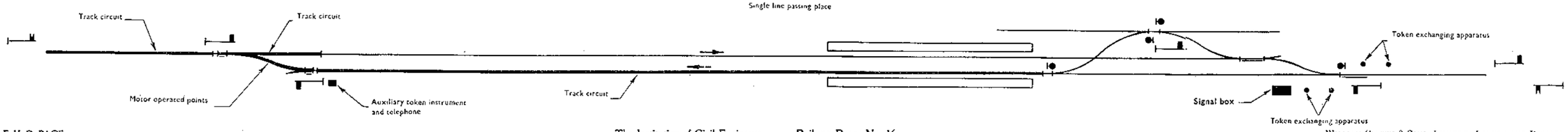


FIG. 15



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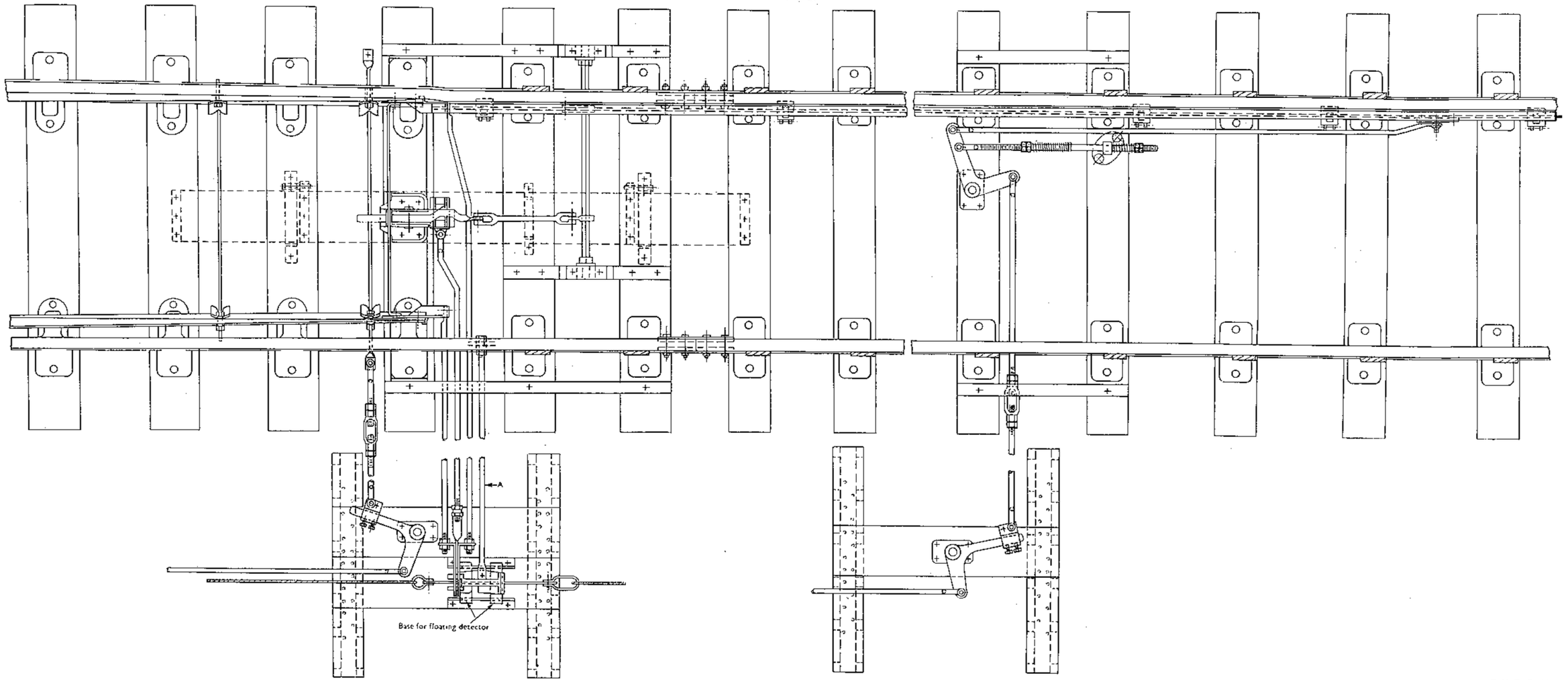
RAILWAY SIGNALLING FOR THE CIVIL ENGINEER

FIG. 2.



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