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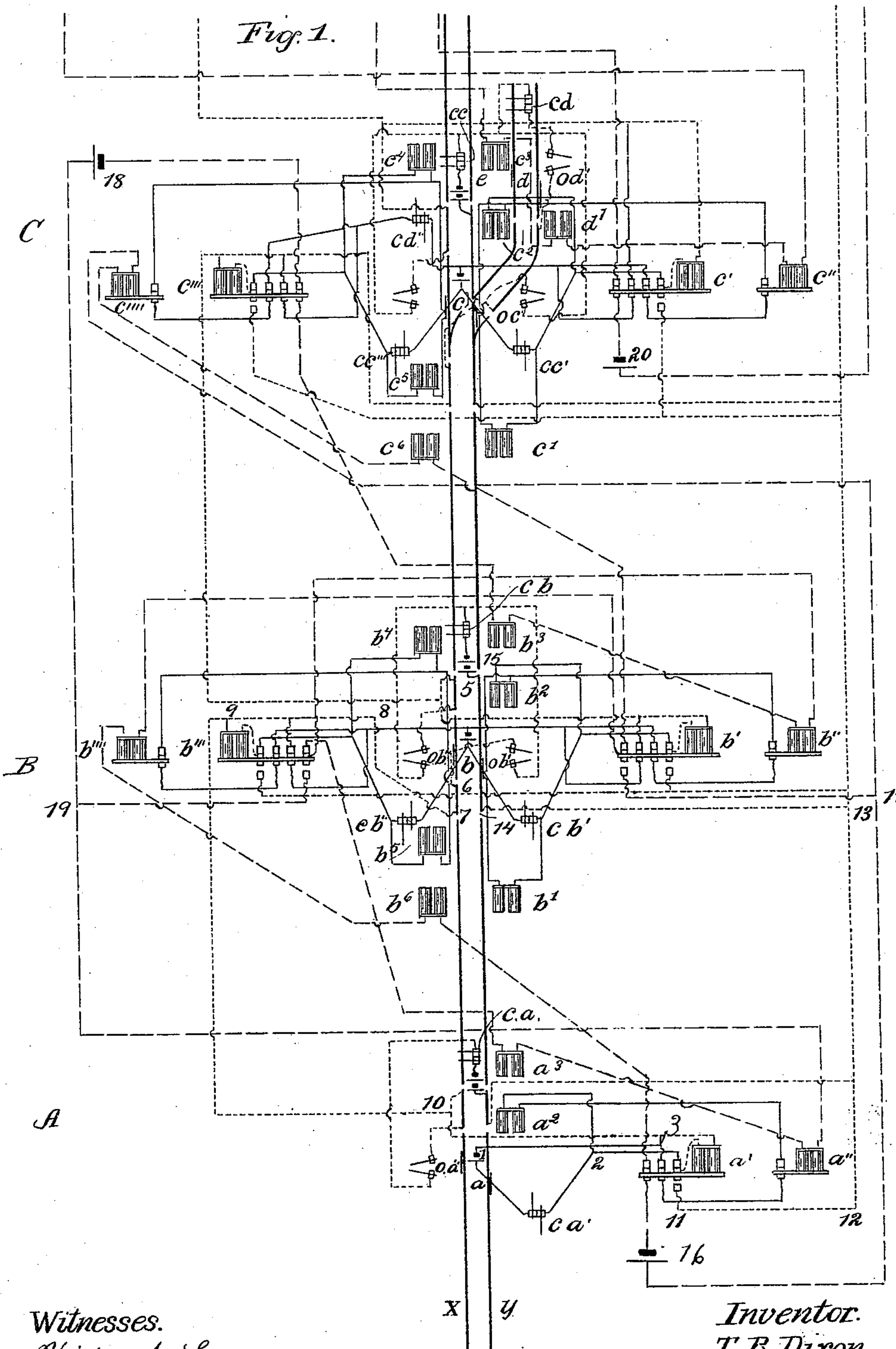
T. B. DIXON.

RAILWAY SIGNALING SYSTEM.

No. 543,591. Patented July 30, 1895.

Fig. 1.



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(No Model.) 10 Sheets—Sheet 2.

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RAILWAY SIGNALING SYSTEM.

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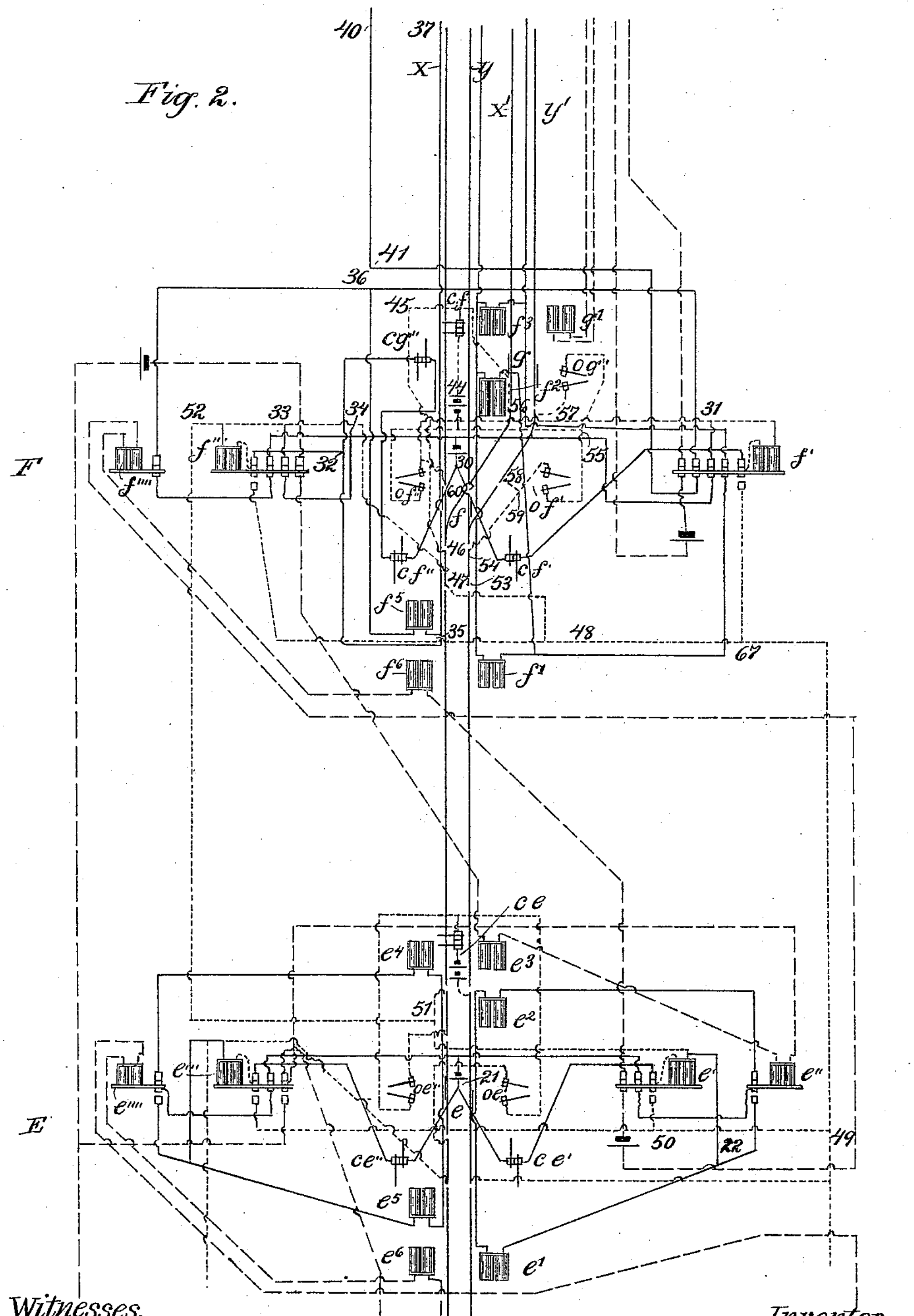
Fig. 2.



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(No Model.) 10 Sheets—Sheet 3.

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RAILWAY SIGNALING SYSTEM.

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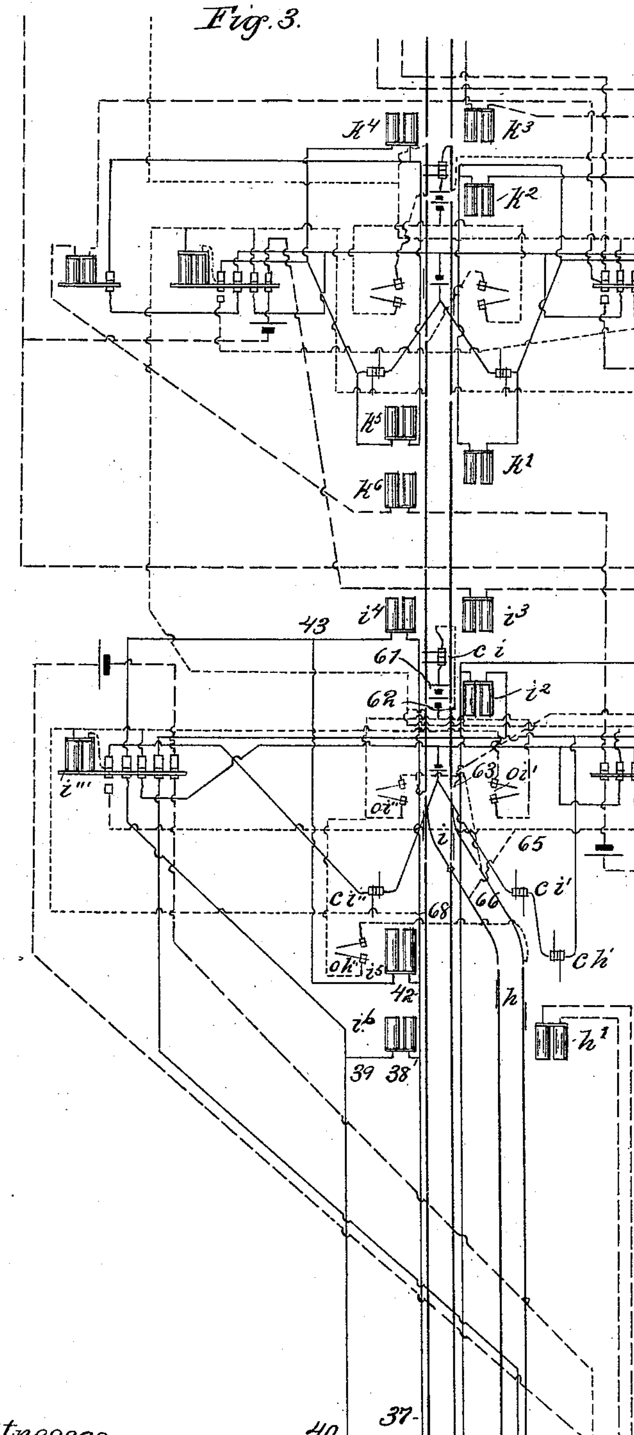
Fig. 3.



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(No Model.) 10 Sheets—Sheet 4.

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RAILWAY SIGNALING SYSTEM.

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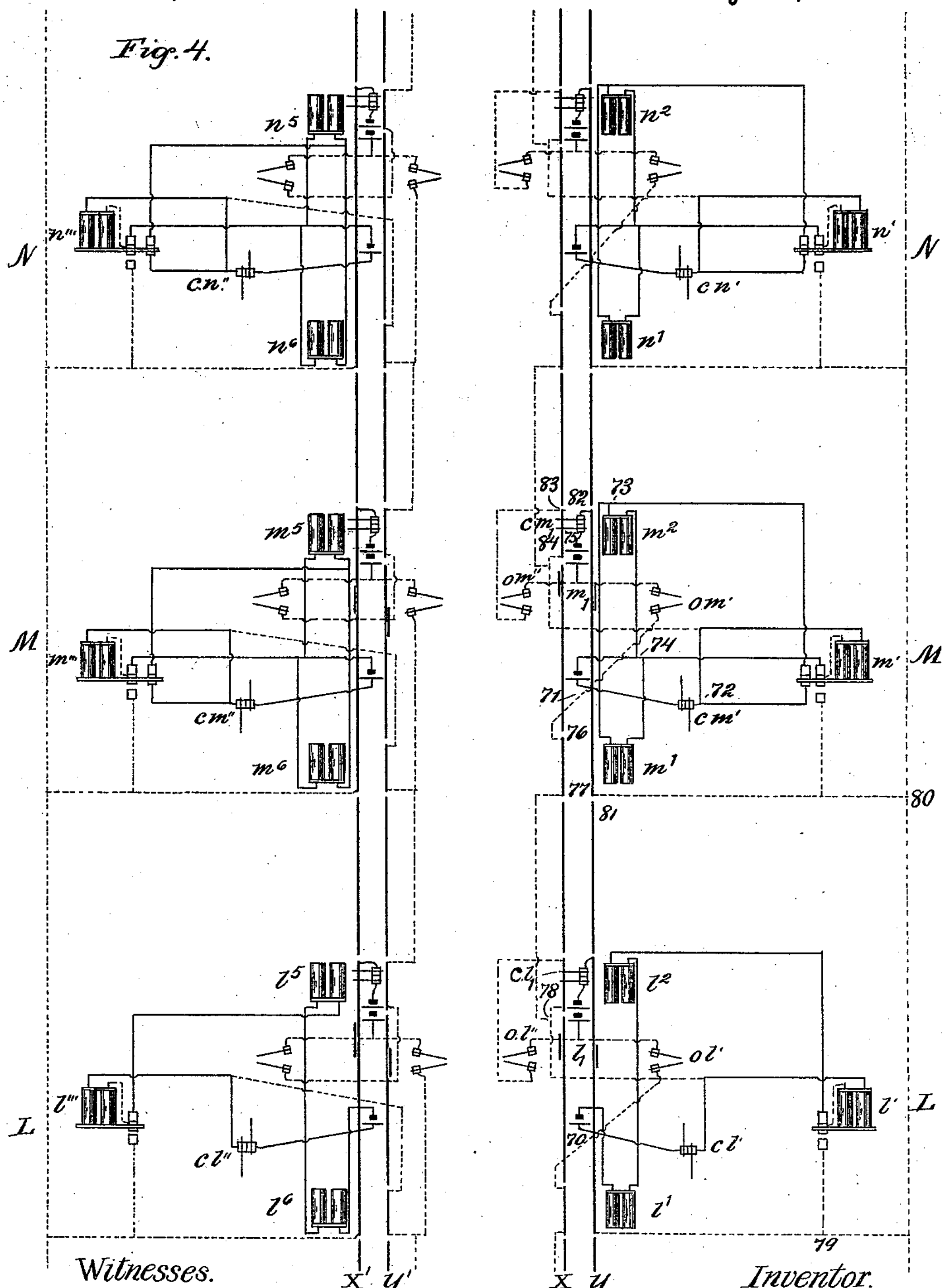

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(No Model.) 10 Sheets—Sheet 5.

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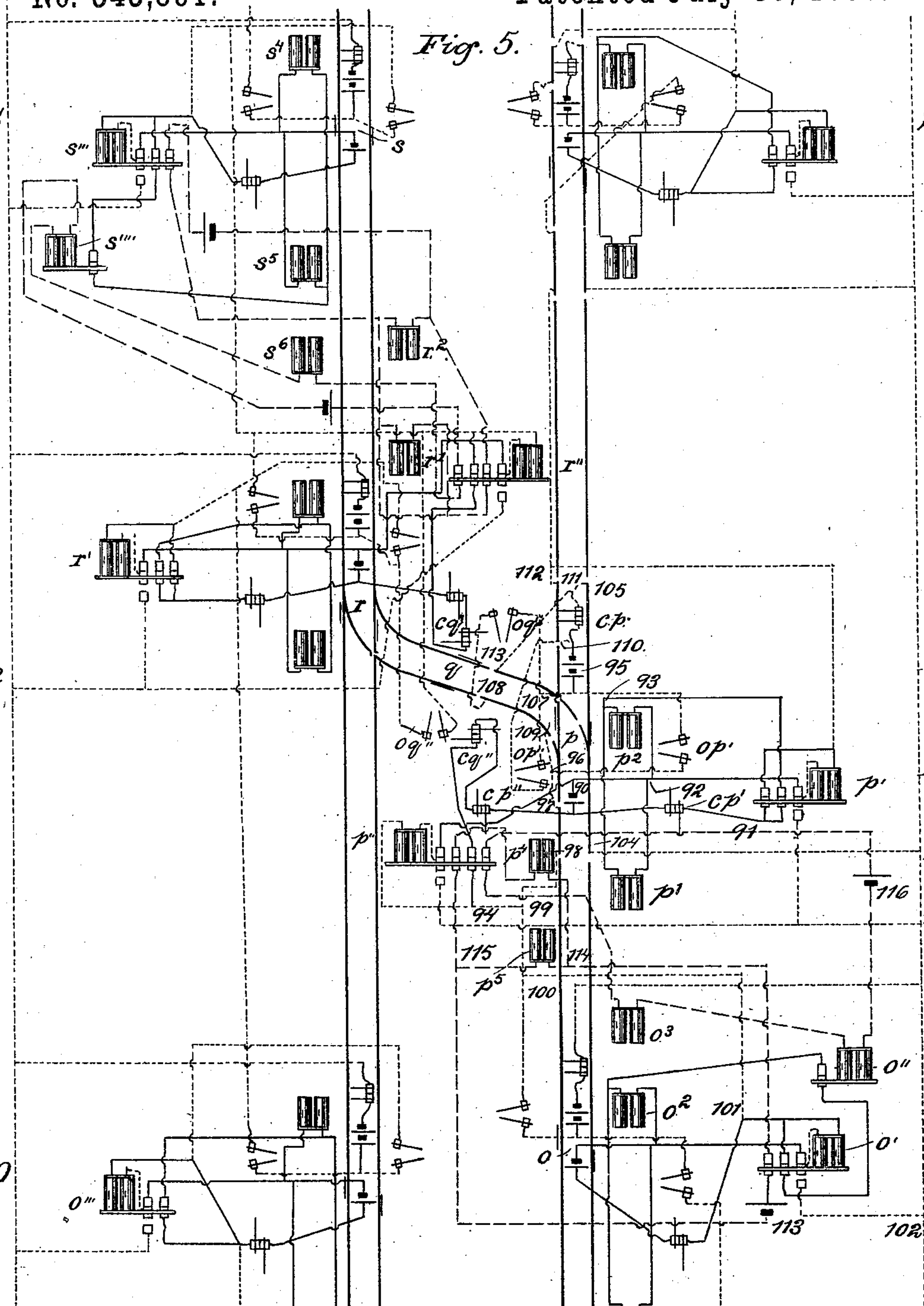
RAILWAY SIGNALING SYSTEM.

No. 543,591. Patented July 30, 1895.

Fig. 5.



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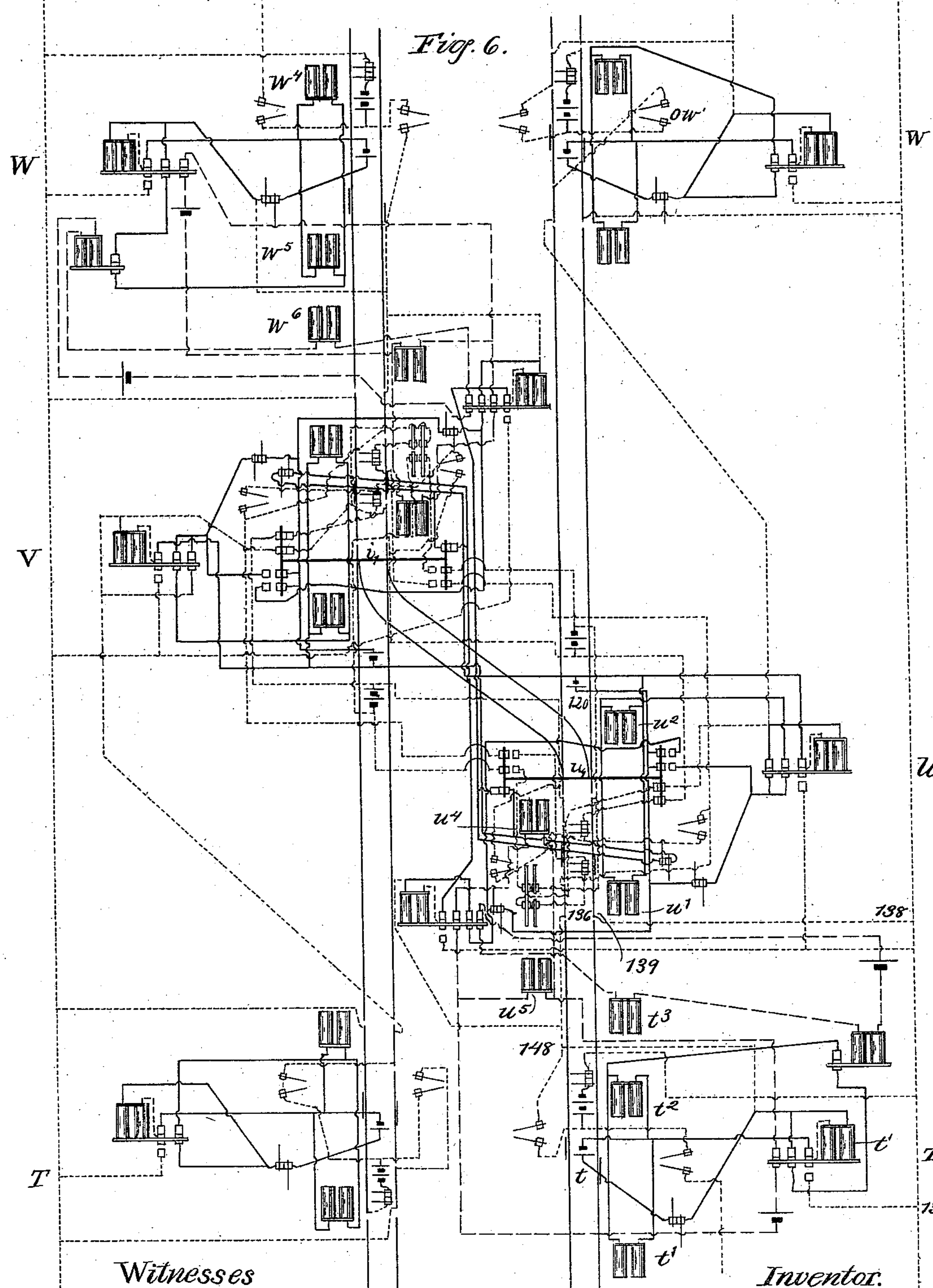
T. B. DIXON.

RAILWAY SIGNALING SYSTEM.

No. 543,591. Patented July 30, 1895.

Fig. 6.



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10 Sheets—Sheet 7.

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RAILWAY SIGNALING SYSTEM.

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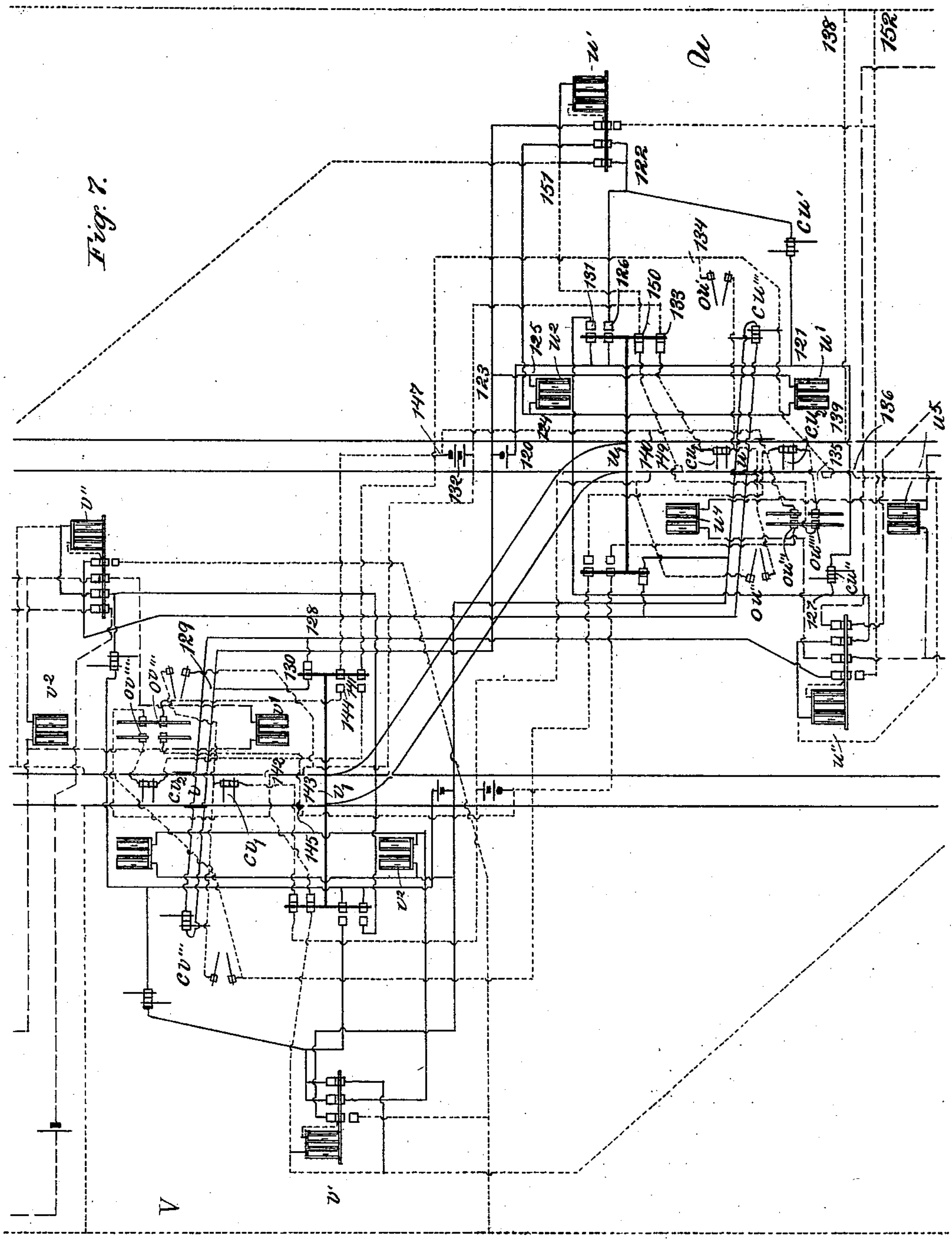

Witnesses.

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(No Model.) 10 Sheets—Sheet 8.

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RAILWAY SIGNALING SYSTEM.

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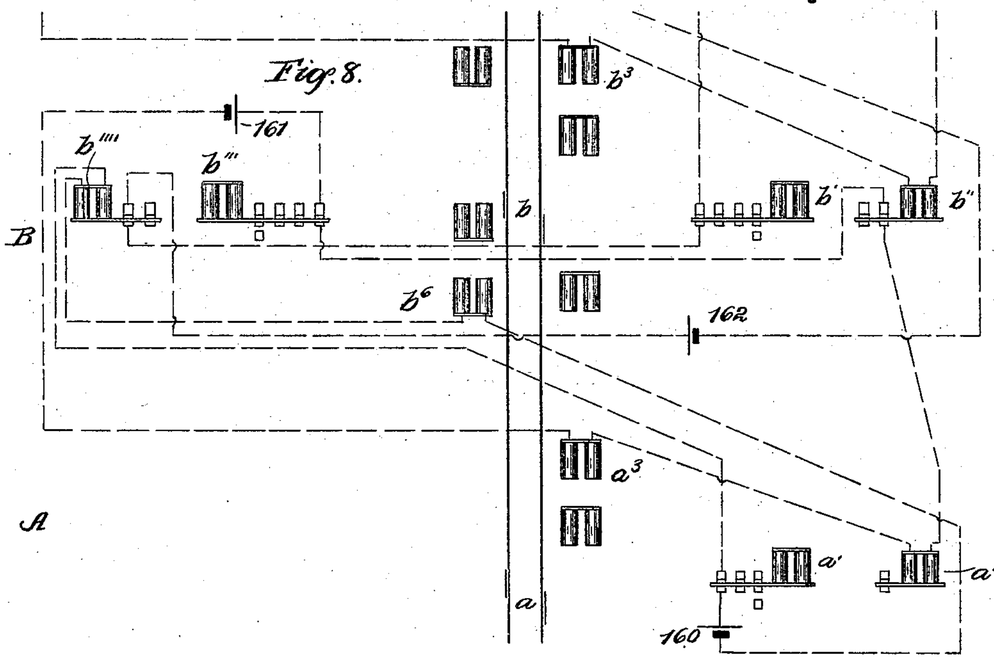

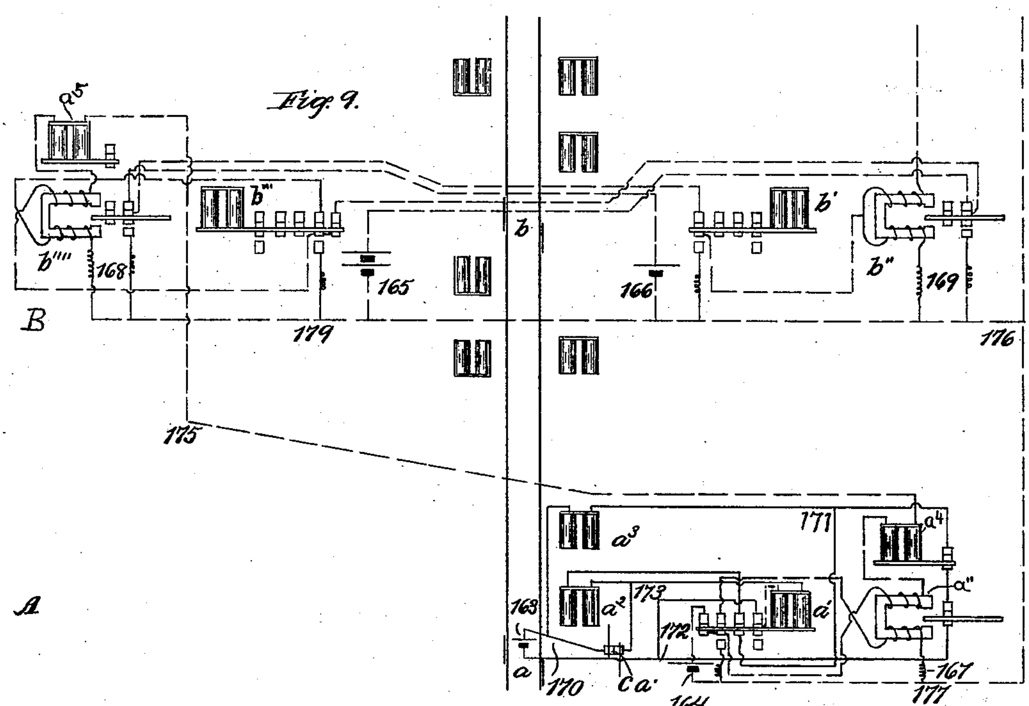

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(No Model.) 10 Sheets—Sheet 9.

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RAILWAY SIGNALING SYSTEM.

No. 543,591. Patented July 30, 1895.

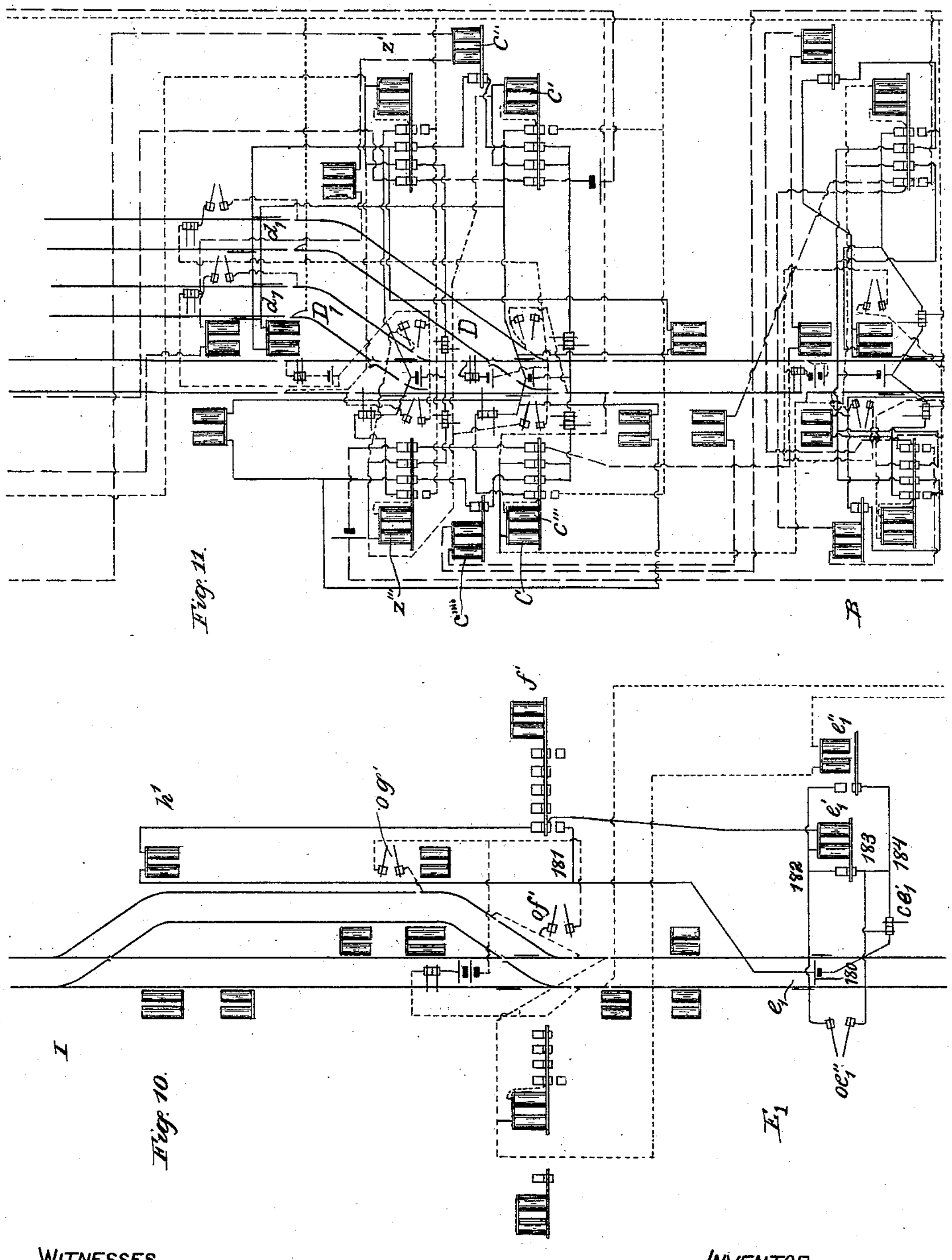

Fig. 11.

Fig. 10.

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10 Sheets—Sheet 10.

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RAILWAY SIGNALING SYSTEM.

No. 543,591.

Patented July 30, 1895.

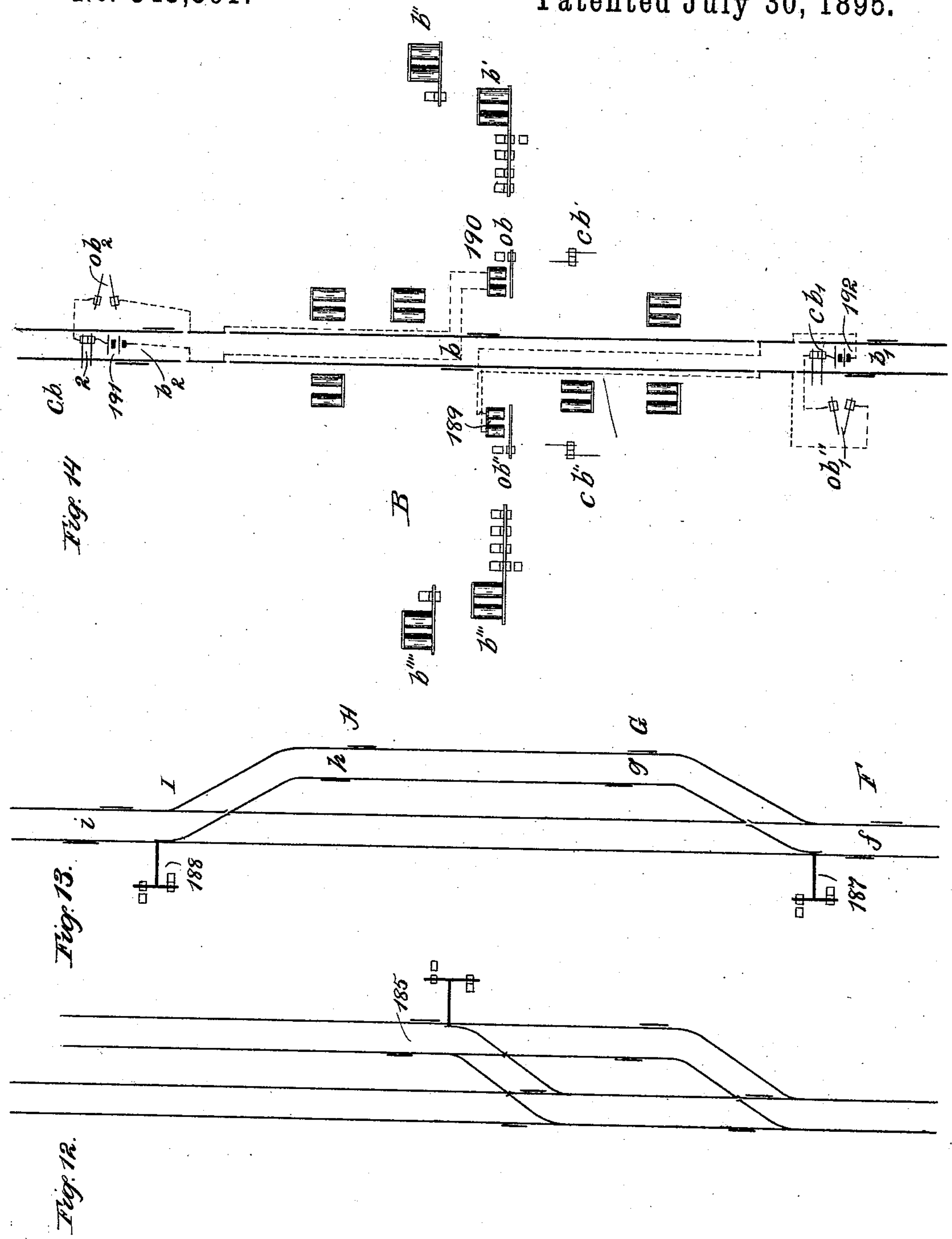

Fig. 14

Fig. 13.

Fig. 12.

WITNESSES

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UNITED STATES PATENT OFFICE.

THOMAS BULLITT DIXON, OF HENDERSON, KENTUCKY.

RAILWAY SIGNALING SYSTEM.

SPECIFICATION forming part of Letters Patent No. 543,591, dated July 30, 1895.

Application filed November 17, 1892. Serial No. 452,358. (No model.)

To all whom it may concern:

Be it known that I, THOMAS BULLITT DIXON, a citizen of the United States, residing at Henderson, in the county of Henderson and State of Kentucky, have invented certain new and useful Improvements in Railway Signaling Systems; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates, generally, to automatic railway signal systems, and particularly to improvements in automatic electrically-operated block-signal systems; and it consists in the novel disposition and arrangement of the signals and in the novel and improved arrangement of the circuits for accomplishing the results hereinafter specified.

In a system of automatic block-signals it is desirable that the arrangement of signals be such that no possible train-movement can be made in which the train-making it will not be fully protected by signals, and also that in certain situations the direction in which a train enters a block shall be indicated by the signals. It is also desirable to have the signals automatically controlled in such a manner that station operators will have the power, without interfering with the operation of the automatic signal-controlling apparatus, to set any of the signals to "danger," so as to block any desired section of road against trains which may be approaching or leaving their stations, and thereby retain such trains at any desired point, the automatic feature of the system remaining undisturbed, however, so that, while an operator may have the power to set a signal or series of signals to "danger" at any time, he can have no power to set them to "safety" when a train is under their protection. It is further desirable that an automatic block system shall be continuous, not only where the line of road is unbroken by branch tracks, but where it is broken by branch tracks of any kind whatsoever, and that its operation shall be such that when a train passes from a main track to a branch track or from one main track to another by a crossover the main-track signals will indicate "danger" until the train shall have passed completely from the main track and beyond their protection, and also that when a train shall be on a branch track it must be held there by the main-track block-signals being at "danger" should it happen that another train is within the block that the train standing on the branch track must enter when it shall pass onto the main track. It is still further desirable that when a train shall pass from one track to another, as from any branch track onto the main track or from one main track to another by a crossover-track, it shall set the main-track signals, under whose protection it is to proceed, to "danger" before it shall pass onto the main track, thereby making it impossible for a train ever to be on any portion of track unprotected by signals.

In an automatic block system it is further desirable that all of the apparatus which serves to automatically control the signals shall be automatically returned to its normal position after the train operating it shall have passed out of the block governed by it, whether that train shall have passed out of the block at the same end at which it entered or at the opposite end.

The objects of my invention are, first, to provide a system of signals, and of electric circuits for operating those signals, which shall be capable of giving correct and unmistakable indication of the condition of the road with reference to the position of trains at all times and under all conditions of traffic; second, to arrange as far as possible the electrical connections so that any accident to the circuits by which they are rendered inoperative shall of itself cause the signals to go to "danger," if at "safety," or shall make it impossible to restore the signals to "safety," if at "danger," until the circuits shall have been placed in working order; third, to prevent false indications due to crossing of the wires; fourth, to render the system economical in the use of battery power and in the number of wires required to operate it; fifth, to render it impossible for a signal to be returned to "safety" until the train which first set it to "danger" shall have passed completely beyond its protection; sixth, to prevent confusion and misunderstanding owing to trains which are moving in opposite directions entering the same block from opposite ends at the same instant; seventh, to so arrange all the signal-circuits that any signal or series of signals may be operated by the station operator or other qualified person for the purpose of stopping or holding trains, but so that the automatic operation of the signals can in no way be interfered with thereby, thus making it impossible for any mistake of the operator to lead to the display of a false signal. These objects are attained in the system of signals herein described, and illustrated in the drawings which accompany and form a part of this application, in which the same reference letters and numerals indicate the same or corresponding parts, and in which—

Figure 1 shows my system of signals applied to a short section of a single-track railway and provides for travel in both directions over this track. It also shows an application of the system to a single-point siding. Figs. 2 and 3, which are to be regarded as one continuous drawing, the track and wires at the top of Fig. 2 and the bottom of Fig. 3 matching, show my system of signals applied to a double-point siding which has a great amount of traffic passing over it, the situation being that common at stations. Fig. 4 shows my system of signals applied to a section of a double-track railway, travel ordinarily being in only one direction on each track. Figs. 5 and 6 show the arrangement of signals and circuits for double-track crossovers, Fig. 5 being the arrangement best adapted to crossover-tracks which are of sufficient length to permit of placing the track-instrument wholly between the two parallel tracks, while Fig. 6 is the arrangement best adapted to situations where the tracks are too close together to permit of placing a track-instrument on the crossover-track. Fig. 7 is an enlarged view of the central portion of Fig. 6. Fig. 8 shows a modified method of operating the front relays and signals. Fig. 9 shows an arrangement for controlling the front relays and signals by means of circuits analogous to those employed in the differential systems of duplex telegraphy, two line conductors being by this means dispensed with. Fig. 10 shows a modified arrangement for controlling special siding-signals. Fig. 11 is a diagram of a track with two sidings branching from it very near together and facing in the same direction. Fig. 12 shows a siding provided with a crossover to the main track, the crossover-track being too short to permit of placing a track-instrument upon it. Fig. 13 shows a side track which is of such length that it is desirable to have it provided with a signal system of its own separate from the main track. Fig. 14 shows a modified method of operating the dotted-line or clearing circuits.

In the drawings I have indicated by different kinds of lines the different classes of circuits used in my system. The full lines represent local circuits, which lie entirely within the signal-stations to which they belong and which directly control the home and distant signals. The dashed lines represent line-circuits, which extend from signal-station to signal-station and the function of which is to control the special front signals, to be hereinafter mentioned, and to set signals in front of a train to protect it in front. In other words, their function is to control the front signals. The dotted lines likewise represent line-circuits extending from signal-station to signal-station, their object being to clear signals in rear of a train when the train has passed under the protection of other signals in advance.

I have designed this system of signals to be operated by a circuit-breaker or track-instrument of my invention, which forms the subject-matter of an application for Letters Patent filed November 17, 1892, Serial No. 452,356. I do not confine myself, however, to the use of any particular track-instrument, my system being adapted to be operated by any track-instrument which will operate signals differently, according to the direction in which a train passes over the track-instrument, which is capable of operating, simultaneously, two or more circuits, either normally open or normally closed, or both, and which is adapted to close a normally-open circuit for an instant only immediately after the passage of the train. The location of this track-instrument at each signal-station I have indicated by two short parallel lines placed just outside the rails, which represent the rail-levers by which the track-instrument is operated. Near these two parallel lines I have diagrammatically represented the various contact-points of the track-instrument in positions best adapted to permit of diagrammatic illustration of their action, without regard to their actual positions in the mechanism of the track-instrument and without attempting to show the means by which they are operated; but in order to operate my system it is not essential that the contact-points herein shown as being a part of the track-instrument shall be mechanically a part of the track-instrument, since they might be located at a distance from the track-instrument and operated indirectly by it in any suitable manner. For instance, they might be operated by an electromagnet the circuit of which is controlled by the track-instrument, or by fluid-pressure devices, or by compressed air, any means of this sort being substantially, though not actually, a part of the track-instrument; and what has just been said in relation to the track-instrument contact-points applies with equal force to the switch-instrument contact-points, to be hereinafter mentioned.

The signals which I propose to use in this system and which are indicated in the diagrams by electromagnets placed by the side of the track, with their poles facing in the directions in which the signals which they represent should face, are of my invention and form the subject-matter of an application for Letters Patent filed July 28, 1892, Serial

No. 441,480. In these signals the signal arm or blade is arranged to be moved into the "danger" position by a weight when the circuit around a controlling-magnet is broken, the signal-arm being returned to position by suitable means when the controlling-magnet is again energized by the completion of the circuit around it. It is this controlling-magnet which in the diagrams is used as a representation of the signal itself, and in the description of the operation of the system it is to be understood that when the circuit of a signal-magnet is broken that signal is placed at "danger" and that when the circuit is closed the signal is restored to "safety."

It is obvious that it is not essential to the operation of my system that this particular signal be used or that a signal which when at "safety" is in a closed circuit be used, since, as will be seen hereinafter, the compound relay or "governor," as I prefer to call it, which directly controls the circuits is as easily adapted to close as to break a circuit by the fall or rise of its armature, since all electrical signals are controlled by a breaking or completion of a circuit around the electromagnet.

In the diagrams I have shown the various circuits controlled by a relay or governor having, except in certain situations to be hereinafter mentioned, a number of sets of contact-points adapted to be operated by the movements of the armature of the said relay or governor, the different sets of contact-points being insulated and adapted each to control a different circuit. This governor is of my invention and forms the subject-matter of an application for Letters Patent filed November 17, 1892, Serial No. 452,357, where it is more fully described. As stated in the specification of this relay, certain of the contact-points are "continuity-preserving" contact-points, so that separate adjustment of the various sets of contact-points is possible and so that it is possible to cause an armature contact-point when the armature falls or rises to make contact with one contact-point before breaking contact with the other contact-point. I do not confine myself to the use of this particular relay or governor, since the system will work equally well with other instruments fulfilling the condition of having the contact-points adjustable and capable of preserving the continuity in the manner above stated; or I may use a number of separate relays placed in the same circuit, some of them being provided with continuity-preserving contact-points. In the diagrams I have likewise shown relays of the ordinary type, whose function is to control the front signals of the system, and for this reason these relays are termed "front relays." Certain of these front relays are provided with continuity-preserving contact-points, and in the modification shown in Fig. 8 the greater number of the front relays have two sets of continuity-preserving contact-points, in this case the construction of the front relays being the same as of the governors. The front relays of Fig. 9 differ from those of the other figures in being polarized relays. The function and operation of all of these relays will be apparent hereinafter.

My signal system is of the class known as "block-signal systems," in which the road is divided into a number of sections known as "blocks," within which, under ordinary circumstances, only one train is allowed at a time. If the road be a single-track, requiring provision for trains running in both directions over it, there are signals at each end of every block, facing so as to be seen by the engineer of a train approaching that block. If the road be a double-track road, travel being ordinarily in one direction only over each track, there is need for signals only at the end of each block which a train will first approach on entering that block. On single-track roads a train must be protected in front from trains going in the opposite direction and in rear from trains going in the same direction, while on double-track roads only the latter protection is required.

On a single-track road or on any section of road where traffic is in both directions over it blocks in front of a train are termed "front blocks" and blocks in rear of a train are termed "rear blocks," because of the manner in which the signals of those blocks are operated. On double-track roads there are no front signals, except at crossovers, and hence no front blocks.

Fig. 1 shows diagrammatically a section of a single-track railway comprising three signal-stations A, B, and C, the track between A and B and B and C constituting in each case a block. In this figure, A is shown as the beginning of the line, and traffic of the kind and character to require protection and control by block-signals is not supposed to extend beyond it, the signal-circuits being modified accordingly. The track is supposed to extend indefinitely beyond station C, being divided into blocks in the same manner that the section of track from A to C is divided.

At C is shown a single-point siding with suitable signal connections therefor, as will be hereinafter described.

Sidings, such as shown at C, will be located at intervals along the track to permit of trains passing. They will usually be located at the point of division between two blocks, though not necessarily at every point of division between two blocks. The signals of the system must be so operated, however, that when a train enters the section of track intermediate between two consecutive sidings on the line that section of track shall be closed to trains going in the opposite direction, so that the train first entering may be in no danger of meeting another train at a point where they cannot pass. Thus in Fig. 1 the signals of the section of track between signal-stations A and C are so operated that a train entering the block A B at A sets signals at A to protect itself in rear from trains following, and it likewise sets signals in front, not only at B, but also at C, to protect itself from trains moving in the opposite direction. A train entering the block B C at C sets signals at stations C, B, and A in a similar manner. A train entering at either end of the section of track A C therefore closes that section of track to trains going in the opposite direction until it shall have passed out of the said section again.

If the only signal-stations within the section of track between two sidings or passing-points be at the ends of the section, then a train entering at one end of this section must not only close this section to trains going in the other direction, but also close the section to trains going in the same direction and retain the section so closed until the train shall have passed out of the section again. It is not convenient or economical, however, under ordinary circumstances, to have sidings on the main track at distances less than several miles apart, while if suitable signal arrangements be provided trains may, and it is desirable that they should, be permitted to follow each other at much shorter distances than the usual distance between sidings on the main line.

On most roads it is necessary, in order to increase to a maximum the amount of traffic possible, with due regard to safety, and to accommodate peculiar conditions of traffic, to permit trains going in the same direction, as, for instance, two sections of the same train, to follow each other at a much shorter distance than the practicable length of that section of track which must be closed to trains going in the other direction. For this reason the section of track between two sidings and passing-points should usually be divided into two or more blocks, except where sidings are quite close together, each block having at its entrance signals which are set to "danger" as the train passes them, while the signals at the entrance of the rear block next behind are returned to "safety" as soon as the train has passed completely out of that block, thus permitting a second train to follow the first at the distance of a block. This feature is illustrated in Fig. 1 and the subsequent figures.

In Fig. 1 the section of track from A to C is divided, as previously stated, into two blocks—viz., the block from A to B and the block from B to C. As will be hereinafter described, when a train has passed from block A B to block B C the rear signals at B for the direction from A to C are set to "danger," while the rear signals at A, previously at "danger," are returned to "safety," thus permitting a train to enter the block A B at A while the first train is in the block B C, but, as will be hereinafter explained, maintaining closed the front block B C at C to all trains from C until all trains from A have left the section of track A C; but in order to permit reverse movements of trains at any point within the section of track between A and C it is essential that the front signals at B set by a train at A for the direction from A to C shall be restored to "safety" after the train shall have passed entirely into the block B C, and, consequently, beyond their protection, and the same is true for all other block-sections comprising a part of my system for a single track or for any track on which trains ordinarily move in both directions. Therefore when a train shall have passed from block A B into block B C the block A B will be clear for the train to again enter it in the direction from B to A—*i. e.*, in the direction opposite to the original direction—provided no second train shall have entered the block A B at A. In case a second train shall have entered at A the front signals at B will indicate "danger," having been set or maintained at "danger" by the second train which entered at A.

The section of track from A to C and the other similar sections of track may be termed "signal-divisions." A signal division-may be defined as a section of track which, when a train enters it at one end, is closed by signals to trains going in the direction opposite to that of the train first named until the first train shall have passed completely out of said division. Such a signal-division may include only one block or it may include a number of blocks, according to the arrangement of the signal-circuits. It will usually have at each end a siding.

In the drawings, contact-points, governors, relays, and signals for the direction from A to C are on the right side of the track and for the direction from C to A are on the left side of the track.

Taking up the diagrams in detail and beginning at signal-station A in Fig. 1, x and y are the track-rails; a, the track-instrument at station A. a^2 is the home-signal at the entrance of the block, and a^3 is a special front signal in a circuit separate from that of signal a^2, the function of which circuit will be hereinafter described. a' is the governor, previously mentioned, which controls the various circuits and from which they radiate. ca' are normally-closed circuit contact-points of the track-instrument a for direction from A to C. 1 is a closed-circuit battery, the circuit of which runs from the positive pole of the battery through the contact-points ca' of track-instrument a to 2, where it branches, one branch going to the third contact-point of the governor a', thence through the coils of the governor-magnet if the armature of the governor be up to 3, and thence back to the negative pole of the battery. The other branch from 2 goes to the coils of signal-magnet a^2, thence through the contact-points of relay a'' and through the second contact of governor a' to 3, and so back to battery.

When a train passes over track-instrument a in the direction from A to C the contact-points ca' are separated, breaking the full-line circuit, and thereby causing the armature of governor a' to drop, at the same time, as previously explained, setting signal a^2 to "danger." It will be noted, however, that at station A both branches of the full-line circuit pass through the contact-points of the governor, the one through the third contact of the governor and the other through the second contact, so that the full-line circuit remains open when, after the passage of the train, the contact-points ca' are brought together. The full-line circuit can then be again completed only by the raising of the armature of governor a', which is the function of the dotted-line circuits, but which is not done until either after the train has passed station B or has reversed its direction and passed over track-instrument a in the direction from C to A. It will be noticed that at station B and the other signal-stations where there are signals for both directions the branch of the full-line circuit which passes through the coils of the governor-magnet is broken in two places by the fall of the governor-armature—viz., at the second and fourth governor-contacts. This is necessary to prevent the completion of a false connection through the contact points of the governor on the opposite side of the track, which, if completed, would render the circuits inoperative.

Omitting for the present description of both dotted-line and dashed-line circuits at station A, and proceeding to station B, b is the track-instrument. b' and b^2 are respectively distant and home signals for station B, and b^3 the special front signal. Signals b' and b^2 are in the same full-line circuit, and must therefore indicate the same at all times. They correspond exactly to the distant and home signals now used almost universally in signaling systems, automatic and otherwise, the function of the distant signal being to caution the engineer of an approaching train as to the condition of the home-signal, and thus give him an opportunity, should the distant signal indicate "danger," to bring his train under control, so that he may not run by the home-signal should it still indicate "danger" when he reaches it.

The full-line circuits of station B are the same as at station A, except that the branch which contains the governor-magnet passes through two contacts of the governor, as previously stated. There is also another branch of the full line circuit which runs from the contact-points cb' through signal b', and thence to signal b^2, where it connects with the full-line circuit leading from b^2 to relay b''. This full-line branch has the effect of placing signals b' and b^2 in multiple, which is usually the best method of connecting the two signals. Under some circumstances, however, it may be advisable to connect the home and distant signals in series, and connections for this purpose will be hereinafter described.

ob' are the normally-open contact-points of track-instrument b, which are closed by the passage of the train over the track-instrument. These contact-points are connected to the dotted-line circuit leading back to the governor-magnet of station A, which circuit is therefore normally open, and their object is to close this circuit when the train passes over the track-instrument. Since these contact-points are brought together by the passing of the first wheel of the train over the track-instrument, if nothing were interposed to prevent, the dotted-line circuit would be completed when the first wheel passed over the track-instrument and the signal a^2 would be returned to "safety;" but at the time the first wheel passes over the track-instrument the main portion of the train is still in the block A B, and it is desirable that the signal a^2 shall not be restored to "safety" until the train shall have completely passed over the track-instrument and out of the block A B, which the signal a^2 protects. To prevent the dotted-line circuit from being completed while the train is passing over the track-instrument, I employ the normally-closed contact-points cb, which are likewise part of the track-instrument and are operated by the depression of the rail-levers. They are separated by the depression of the rail-levers an instant before contact-points ob' are brought together and remain separated so long as the train is passing over the track-instrument, being closed again when the train has passed an instant before contact ob' is broken, thus closing for an instant the dotted-line circuit. The means by which the contact-points are operated to effect this result is fully described in the specification of my track-instrument referred to above.

Before following out the dotted-line circuits it is necessary to consider one peculiarity in the adjustment of the set of contact-points next to the magnet in each of the governors, this set of contact-points being the one to which the dotted-line circuit is connected. The armature contact-point is adapted to make contact with two contact-points—with one when the armature is attracted to the magnet and with the other when the armature is down or away from the poles of the magnet. These contact-points are continuity-preserving contact-points and follow the movements of the armature to some extent, and the adjustment is such that contact is made with one contact-point before contact with the other is broken.

Taking now the dotted-line-circuit connections, remembering that the armatures of governors a' and b' are down, and beginning at the open-circuit battery 5 at station B, the circuit runs from the negative pole of the battery through contact-points cb and ob' to 6, which is at one end of an insulated section of the left-hand rail, the purpose of which will be hereinafter described, through the rail to 7, thence to 8, to 9, to 10 at station A, through the magnet-coils of the governor to 11, to a dotted-circuit return-wire at 12, over the return-wire to 13, thence to 14 at one end of an insulated section of the right-hand rail, through the rail to 15, and thence to the positive pole of the battery. When the circuit is completed through the coils of the magnet of governor a' the armature is attracted and rises, thereby closing the full-line circuits and restoring signal a^2 to "safety." The completion of the full-line circuits re-establishes the flow of the electric current from battery 1 through the coils of governor a' and keeps the magnet energized after the dotted-line circuit is broken, this circuit being complete for only a very short time.

In making connections for the full-line and dotted-line batteries the poles of the batteries should be so connected with their circuits that during the instant when currents from both batteries are flowing through the coils of the governor-magnet both currents will flow in the same direction, so as not to neutralize each other.

As has been seen, certain sections of the track-rails are insulated from the rest of the track, the insulation being indicated in the diagrams by breaks in the line of rails, and these insulated sections of track form a portion of the system of electrical circuits. The left-hand rail has two of these insulated sections, one on each side of the track-instrument, with a central section containing the track-instrument. The right-hand rail has one insulated section, the ends of which match the extreme ends of the insulated sections of the left-hand rail. The purpose of these insulated sections is to prevent the clearing of signals in rear of a train when its stops over the track-instrument with the rail-levers between two trucks—*i. e.*, with no wheel on them. Under these circumstances the effect on the track-instrument contact-points is the same as though the train has completely passed, and, without special means to prevent, the signals would be returned to "safety" by the completion of the dotted circuit through the contact-points *cb* and *ob'*, or their corresponding contact-points at other stations. The insulated sections of track prevent this by short-circuiting the dotted-line circuit through the wheels and axles of a car. For instance, supposing a train from A at station B to stop over the track-instrument *b* in such a position as to permit the rail-levers to rise between the wheels, then the contact-points are operated as though the train had left the block A B and the dotted-line circuit is for an instant completed, since the contact-points *cb* are brought together an instant before contact-poinst *ob'* are separated; but some car of the train will then be on the insulated section of track between A and B, which insulated section is somewhat longer than a car and is placed as close as possible to the track-instrument, and the dotted-line circuit will be short-circuited between the points 7 and 14, thus preventing the magnet of governor a' from being energized so long as the car stands on the insulated section. Where it is desired to arrange the system to work under what is known as the "permissive block system," these insulated sections may be united into one insulated section extending throughout the block, as shown in Figs. 2 and 3, in the block lying between the points of the double-point siding.

I have described thus fully the object and operation of the insulated sections of track in order that their function in the operation of the system may be apparent. They are, however, properly a part of the track-instrument and have been so described in the description of my track-instrument. In the application for my track-instrument I have also described a purely mechanical arrangement for accomplishing substantially the same result that the said insulated rail-sections accomplish, and which may be employed in this system; but in general I prefer the insulated rail-sections, and have therefore confined myself thereto in the drawings which form a part of this application.

Passing on to station C, the full-line-circuit connections for the direction from A to C are the same as at station B. The dotted-line circuit is slightly changed to provide for the clearing of signals when a train passes from the main line to the siding. Since when a train passes onto the siding the effect on the signal-circuits, so far as the setting of signals to "safety" is concerned, should be the same as if the train had passed on into the block beyond C, it is sufficient to place a track-instrument *d* on the siding beyond the fouling-point and connect its contact-points *cd* and *od'* in multiple with the contact-points *oc'*, so that the effect on the signals is the same whether contact *oc'* or *od'* is closed. Insulated sections of track are used on the siding to prevent the clearing of the signals in case the train does not pass completely over the track-instrument.

It should be noted that the insulated sections of track may serve the same purpose as the dotted-line-circuit normally-closed contact-points—such as *cb* or *cc*—by short-circuiting the battery through the wheels of a car instead of breaking the circuit. Short-circuiting the battery, however, has a very deleterious effect on it, and for this reason the contact-points *cb'*, &c., are employed to reduce so far as possible the necessity of short-circuiting the battery.

For the direction from C to A the full-line circuits at C are the same as on the right side of the track, except that the normally-closed contact-points *cd''* of track-instrument *d* are placed in series with the contact-points *cc''* of track-instrument *c*, so that the same signals are set to "danger" in the division A C whether a train enters the division from beyond C or from the siding at C; but, as will be seen, a train entering the division from the siding sets the signals to "danger" when the first wheels of the train pass over the siding track-instrument, and, consequently, before it reaches the main track. The dotted-line circuits are the same as at B on the right-hand side of the track. At B the connections are the same on both sides of the track. At A, since it is the terminus of the line and there are no signals to set to "danger," the only circuits necessary are the dotted-line "clearing-circuits."

The dashed-line circuits, which include the special front signals, as a^3 b^3, &c., are two in number, one for each direction. They have two objects: first, to set signals in front of a train to protect it from trains moving in the opposite direction, and, second, to operate the special front signals.

The object of providing the special front signals will be seen from the following considerations: Suppose that two trains enter the division A C, one at A and the other at C, at the same instant. Then the train at A, passing over the track-instrument a, sets the signal a^2 to "danger" as a rear signal, and at the same time, by means of the dashed-line circuits, in a manner to be hereinafter described, sets to "danger" signals c^4 and c^5 at C, also b^4 and b^5 at B. The train at C will likewise set to "danger" signals c^4 and c^5 at C, b' and b^2 at B, and a^2 at A; but if the trains enter the division simultaneously, or nearly so, the engineer of each train will see the home-signal of that station at which he then is set to "danger," and will yet suppose that it is his own train which has set the signal as a rear signal, whereas the signal may have been set as a front signal by the train at the other end of the division. In this way, if there were no intermediate signal-station B, the trains might come into collision. This confusion of signals I avoid by the use of the special front signals, which are set only by trains moving in the direction opposite to that of the trains which they are to warn. Thus a train entering the division at A sets to "danger" signal a^2, does not change the condition of signal a^3, and sets to "danger" signals c^4, c^5, and c^6 at C and b^4, b^5, and b^6 at B. In like manner a train entering at C sets to "danger" only signals c^4 and c^5 at C, while it sets signals a^2 and a^3 at A and b', b^2, and b^3 at B. Therefore if the engineer of a train entering the division A C at A should see not only signal a^2 but also signal a^3 go to "danger" he is thereby warned that at the same instant a train is also entering the division at C, and confusion is thereby rendered impossible.

Signals a^2 and a^3, and the others like them, are really separate signals, but since they are always together they may be mounted as separate signal-blades in the same signal-box or on the same signal-pole, and in my application for Letters Patent for electric railway-signals, Serial No. 441,480, I have shown how these two signals may be combined in this manner. It will be evident that it is not essential in order to avoid confusion that the regular home-signals, as well as the special front signals, should be set as front signals; but, as will be seen, no objection exists to operating the home-signals as front signals, and in my signal above referred to, in which both blades are within one case, it is essential that both blades be operated as front signals, and I have therefore shown the circuits so arranged that both signals are set as front signals; but if it should be found desirable a slight change in the connections is all that is required to have only the special front signal operated as a front signal. This may be accomplished by making the front relay break the circuit of only the distant or caution signal, as b', without affecting the circuit of the home-signal, since it is evident that the same distant signal answers equally well for both rear and front signals. In my description of the signal referred to I have described how the front relays may be combined with the governing-magnets of the special front signals by providing the armatures of those magnets with contact-points. Where my signal is used in connection with this system I consider this double use of the governing-magnet very desirable, since it reduces the number of electromagnets required.

The three most important classes of signals used in my system—viz., distant, home, and special front—should be distinguished in some way from each other by the color, position, or form of the blade, so that they may not be mistaken for each other. The function of the distant signal is purely cautionary, while home and special front signals are properly "danger" signals, except where trains are run under what is known as the "permissive-block" system, where these signals likewise become cautionary, but indicate the necessity of great caution; but even in the permissive-block system the special front signals should be held to indicate "danger" at some special locations.

I have shown in my diagrams other signals besides those belonging to the three classes just named. These signals, however, are of infrequent occurrence, being used only in special localities, and may receive any proper designation.

The dashed-line circuits are as follows: Taking first the circuit which controls the signals set by a train entering the division A C at A the line runs from battery 16 at A through the first contact of the governor a' to signal b^6, thence through the magnet of relay b'''' to the first armature-contact of governor b', through that contact if the armature be up to signal-magnet c^6, thence to the magnet of relay c'''', and thence by return-wire to battery 16. The lower contact-point of the first contact of governor b' is likewise connected to the return-wire at 17. It will be seen that when a train passes over track-instrument a in the direction from A to C, breaking contact c a' and causing the armature of governor a' to fall, this dashed-line circuit is broken, setting to "danger" signals b^6 and c^6, and allowing the armatures of relays b'''' and

and c'''' to fall, thereby breaking the signal-circuits which pass through their contact-points, and setting to "danger" signals b^4, b^5, c^4, and c^5, but not affecting the governors. When the train has passed on to B, thus causing the armature of governor b' to fall, and has raised the armature of governor a', a dashed-line circuit is completed from battery 16, through the first contact of governor a' to signal b^6, through the magnet-coils of relay b''''; through the first contact of governor b' to 17, and thence by return-wire back to battery. The other dashed-line circuit runs from battery 18 at station C through the first contact of governor c''' to signal b^3, thence through the magnet-coils of relay b'' through the first contact of governor b''' to signal a^3, through the magnet-coils of relay a'' to a return-wire, and thence back to battery 18. The lower first-contact point of governor b''' is connected to the return-wire at 19. The operation of this circuit is the same as that of the circuit of battery 16.

At station C there is still another dashed-line circuit-battery 20, the circuit of which passes through the first contact of governor c'. Another dashed-line circuit passes through signal c^3, signal d', and relay-magnet c''. Both of these circuits properly belong to the block beyond C and correspond exactly to the dashed-line circuits at station A. The signal d' is a special siding-signal, the object of which is to warn the engineer of a train on the siding if there is a train on the block beyond C and coming toward C.

In Figs. 2 and 3, which, as previously explained, are to be regarded as one continuous diagram, I have shown an application of my system to a double-point siding of such length and importance as to require the most complete signal system. The siding is of medium length and is provided with an arrangement of signals designed to fully provide for every possible train movement; but, as will be hereinafter described, the arrangement of signals here shown may be modified, as required, in order to accord better with the length of the siding, the traffic of the road, and other conditions that will be mentioned, where these conditions differ from those presupposed here. In these figures x and y are the rails of the main track, x' and y' the rails of the siding, F and I signal-stations at the two ends of the siding, and E and K advance-signal stations at either end, the purpose of which is to stop switching between stations F and I when a train reaches either of the advance-stations or to stop an approaching train at the advance-station should a train be approaching it from the siding-stations. The sections of track between stations E and F and I and K constitute each a division for the direction approaching the siding, but only a block for the other direction, leaving between them a division F I. The circuits at E and K do not depart from the ordinary except for a change in the signal-circuits at station E, which does not affect the operation of the signals, and which will be hereinafter described. At stations F and I and in the block between F and I there are some differences in the circuits, due to the peculiar conditions there existing, which will be now considered. These differences are principally in the full-line circuits, which here are not local circuits, but connect stations F and I, though there are one or two slight changes in the dotted-line circuits.

Considering, first, the full-line circuits and beginning at station F on the right-hand side of the track, one circuit begins at the positive pole of battery 30, runs through the normally-closed contact-points cf' to the fifth contact of governor f', thence, if the governor-armature be up, through the coils of the governor-magnet to 31, thence through the third governor-contact to the negative pole of battery 30. This circuit, it will be seen, is the ordinary local full-line circuit without the branches for the signals f' and f^2 of station F, which are in a circuit, the battery of which is at station I, but which passes through the fourth contact of governor f', so that these signals are set to "danger" by the fall of the armature of f'. Leaving for the moment this last circuit and taking up the full-line circuit on the left side of the track at station F, it runs from the positive pole of battery 30 through normally-closed contact-points cf'' of track-instrument f, through normally-closed contact-points cg'' of the siding-track instrument g to 32, where it divides, one branch going to the fourth contact of governor f''', thence through the coils of the governor-magnet to 33, and through the second governor-contact to 34. The other branch runs from 32 to 35, where it again divides, one branch going through signal f^5 to 36. The other branch from 35 runs to 37, thence, in Fig. 3, to 38, where it divides, one branch going through signal i^6, which, though operated by a full-line circuit, is really a special front signal, thence to 39, where it again joins the other branch from 38, which branch will be hereinafter described, thence to 40, to 41, in Fig. 2, and thence through the second contact of governor f' to 36. The two branches at 36 unite over a common return-wire, which runs through the contact of relay f'''' and through the third contact of governor f''' to 34, where it unites with the first-mentioned branch of the full-line circuit over a common return-wire to the negative pole of battery 30. The remaining branch of this circuit runs from 38, in Fig. 3, to 42, where it divides, one branch containing signal i^5, the other branch containing signal i^4, the two branches uniting at 43, thus placing signals i^4 and i^5 in multiple, and running through the fourth contact of governor i''' to 39, where it unites with the other branch from 38, as previously mentioned. So far as the actual connections are concerned, these circuits just described are in effect the ordinary signal-circuits, such as the circuits shown at station K, but with three distant signals i^4, i^5, and i^6, instead of one, all connected in multiple, and with special means for setting to "danger" signals i^4 and i^5 and i^4, i^5, and i^6, which thus become capable of a double use. Signal i^5 is not to be regarded as the ordinary home-signal, which usually indicates "danger." In localities such as this it will generally be impossible to adhere strictly to the absolute block-system, and signal i^5 and its mate f^2 should be regarded rather as signals indicating the need of especial caution. Signals f^3 and i^6 also indicate "great caution" rather than absolute "danger."

The full-line circuits of station I are similar to those of station F, that circuit of station F previously mentioned as running through the second contact of governor f', which, being part of a circuit corresponding exactly to the circuit just described, as starting on the left side of the track at station F. Signals f', f^2, f^3, i^2, and i^3 correspond, respectively, to signals i^4, i^5, i^6, f^5, and f^6. Signals g' and h' are special siding-signals, placed each at one end of the siding and differing in no respect in function from signal d' at station C, in Fig. 1, the only difference in their connections being that both g' and h' are each in a separate circuit having its own battery and passing through a contact of a governor at the opposite end of the siding from the signal which it controls, a plan which, if desired, may be adopted for signal d'.

The dotted-line circuits at stations F and I are only slightly different from those at station C, the differences being caused by the fact that the entire length of the rails between stations F and I constitute insulated sections of track and form a part of the dotted-line circuits. Taking the circuit at station F, it runs from battery 44 through the normally-closed contact-points cf' to 45, thence to 46 at one end of an insulated section of the left-hand rail, thence to 47, to 48, to 49, at station E, to 50, to the third contact of governor e', through that contact, if the armature be down, to the governor-magnet coils, thence to 51, to 52, at station F, to 53 at one end of an insulated section of the right-hand rail, to 54, to the normally-open contact-points of, to 55 and back to battery. A branch runs from contact-points cf to 56 on the left-hand siding-rail, the part to which this wire is connected being in electrical connection with the right-hand rail of the main track between the points of the siding. Another branch runs from the negative pole of the battery to the normally-open contact points of' and then to the magnet of governor f', being also connected at 60 with the left-hand rail of the main track between the points of the siding. Should a train pass out of the block F I from station F while there are still other cars on the block between F and I, or should the train stop over the track-instrument f, battery 44 will be short-circuited between the rails of that portion of the main track between the siding-points at the instant its circuit is completed through the closing of contact cf an instant before contact of'' is broken, and clearing of the signals will thus be prevented. Contact-points og' of the track-instrument g are placed in multiple with contact-points of' of track-instrument f by a wire leading from 55 through contact og' to 57, through the siding-rail to 58, and thence to 59.

The dotted-line circuit-connections of station I are the same as those of station F.

At station E is shown a modification of the signal-circuits by which the home and distant signals are placed in series instead of in multiple, as is the case at the other stations, an arrangement that may be of advantage under some circumstances. The circuit runs from battery 21 through the normally-closed contact-points ce' of track-instrument e, to the third contact of governor e', thence through the coils of the magnet of governor e' to 22, where it divides, one branch going to signals e' and e^2 and to the upper contact-point of relay e'', thence through the armature contact-point to the second contact of the governor and back to battery. The other branch from 22 goes to the lower contact-point of relay e''. This relay e'' has two continuity-preserving contact-points engaging with one armature contact-point, the adjustment being such that when the armature rises or falls contact is made with one contact-point before contact with the other is broken. The operation of this circuit is the same as that of the other full-line circuits where the signals are in multiple. The branch from 22 to the lower contact-point of relay e'' is to prevent the magnet-circuit of governor e' from being broken by the fall of the armature of relay e'', which would make it impossible for the signals to be returned to "safety" by the completion of the circuit through the magnet-coils of relay e''.

Before referring to Figs. 4, 5, 6, and 7, which show my system of signals applied to a double-track railway, I will describe the operation of the system when applied to a single-track railway. (Shown in the figures already described.) The operation of the double-track signals will be described separately.

The operation of my system of signals, as applied to a single-track railway, is as follows: Taking first Fig. 1, and supposing a train to enter the division A C from A when the rail-levers of the track-instrument are depressed, the contact-points ca' are separated, breaking the full-line circuit, thus allowing the armature of governor a' to drop and setting to "danger" signal a^2 as a rear signal to protect the rear of the train from any other train which may desire to follow. The fall of the armature of the governor breaks the dashed-line circuit of battery 16, setting to "danger" signal b^6, causing the armature of relay b'''' to drop, thereby breaking the signal-circuits passing through the contact-points of that relay and setting to "danger" signals b^4 and b^5, setting to "danger" signal c^6 and causing the armature of relay c'''' to fall, thereby setting to "danger" signals c^4 and c^5. The division is thus completely closed to trains desiring to enter it at either C or A. Should the train, after entering at A, desire to back out at A again, when in its backward movement it passes over track-instrument a, the dotted-line open-circuit contact-points oa'' will be closed and the contact-points ca separated, and when the train has passed completely over the track-instrument the contact ca is closed an instant before the contact oa'' is broken, thus completing momentarily a circuit from the dotted-line circuit-battery at A through contacts ca and oa'', and through an insulated section of rail to the magnet-coils of governor a', and thence through the third contact of governor a' to 11, and by return-wire to battery. Should the train stop over the track-instrument with the wheels in such a position as to allow the rail-levers to rise and by operating the contact-points complete the circuit momentarily, the battery will be short-circuited by current passing through the wheels and axles from the insulated section on one side of the track to the insulated section on the other side of the track, thus preventing the raising of the armature of governor a' until the train has passed completely out of the block A B. The raising of the armature of governor a' completes the dashed-line circuit of battery 16 and restores to "safety" signals b^6, b^5, b^4, c^6, c^5, and c^4. The raising of the armature likewise completes the full-line signal-circuit at station A, thus restoring to "safety" signal a^2. Supposing the train to again enter the division A C at A, setting to "danger," as before, signals a^2, b^6, b^5, b^4, c^6, c^5, and c^4, and then to pass on over the division, when it reaches signal-station B, it operates track-instrument b, breaking contacts cb and cb' and closing contact ob'. The breaking of contact cb' breaks the full-line circuit, setting to "danger" signals b' and b^2 and causing the armatures of governor b' to fall. When the train has passed over the track-instrument the contact cb is closed an instant before contact ob' is broken, thus completing the dotted-line circuit as follows: from the negative pole of battery 5 through contacts cb and ob' to 6, through the rail to 7, thence to 8, to 9, to 10 in station A, through the magnet-coils of governor a', through the third governor-contact to 11, to 12, and over a return-wire to 13, to 14, thence through the rail to 15, and to the positive pole of battery 5. The completion of this circuit raises the armature of governor a', thus re-establishing the full-line circuit through the coils of the governor-magnet and retaining the armature up after the dotted-line circuit is broken at contact ob'. The raising of the armature completes the circuit of the signal a^2, also the dashed-line circuit from the negative pole of battery 16, through the first contact of governor a', to signal b^6, through the magnet-coils of relay b'''' to the first armature-contact of governor b', thence through the lower first contact-point to 17, and thence by return-wire back to battery. The completion of this circuit restores to "safety" signal b^6 and raises the armature of relay b'''', thereby completing the signal-circuit passing through that relay and restoring to "safety" signals b^5 and b^4. The train is thus free to back again after passing station B without having to disregard any danger-signal. Should the train stop at station B with part of the train still in the block A B, and with the wheels in such a position that the rail-levers of track-instrument b may rise, thereby operating the contact-points of the track-instrument, and, since contact cb is closed an instant before contact ob' is broken, completing the dotted-line circuit momentarily, the battery 5 will be short-circuited between points 7 and 14, the current passing across the track through the wheels and axles of a car, thus preventing the raising of the armature of governor a'. Passing on to station C, when the train passes over track-instrument c, it sets to "danger" signals c' and c^2, and causes the armature of governor c' to fall, thereby breaking the circuit of battery 20 and setting to "danger" the front signals in the division beyond C and completes the dotted-line circuit, thus raising the armature of governor b' and restoring to "safety" signals b', b^2, c^6, c^5, and c^4, thus leaving the division A C open from end to end. Should the train, instead of passing out of the division at C, enter the siding there, it will pass over siding-track instrument d, separating contact-points cd and closing contact od', and when the train has passed completely over the track-instrument d and so has left the main track clear the contact cd is closed an instant before contact od' is broken, completing the dotted-line circuit through the coils of the governor-magnet of governor b' as follows: from open circuit-battery at C through contact-points cc, cd, and od', through the right-hand rail-section of the siding and the left-hand rail-section of the main track, and through the dotted circuit-conductor to station B, through the magnet of governor b', and through the fourth contact of governor b', the armature of which is down, to the return-conductor, and thence back to battery, thus restoring to "safety" all signals in the division A C yet at "danger." When the train passes from the siding to the main track, it will break the contact cd'', which is in series with the contact cc'', causing the armature of governor c''' to fall and setting to "danger" signals c^4, c^5, b^3, b^2, b', a^3, and a^2.

The operation of the signals for trains going from C to A is in all respects the same as for trains going from A to C.

The necessity for the special front signals will now be seen. When a train enters the division A C at A, it sets to "danger" signal a^2, thereby protecting its rear and assuring the engineer that the signal-circuits are in working order. It will likewise set to "danger" at the other end of the division signals c^4, c^5, and c^6. In like manner a train entering the division A C at C sets to "danger" signals c^4 and c^5 as rear signals and at the other end of the division signals a^2 and a^3. If there were no special front signals the engineer at A, seeing signal a^2 go to "danger," might suppose that his own train had set it, while in reality it was set by the train entering at C. In like manner an engineer at C, seeing signal c^5 go to "danger," might suppose that his own train had set it, whereas it was set by a train entering the block at A. Confusion, misunderstanding of signals, and accident might thus result; but by use of the special front signals, set from a distant station in front, I avoid this ambiguity. An engineer at A, seeing both signals a^2 and a^3 go to "danger," knows that a train is entering at C. In like manner an engineer at C, seeing both signals c^5 and c^6 go to "danger," knows that a train is entering at A. The special siding-signal d' at station C is in series with signal c^3 and is set by a train entering the block beyond C and coming toward C. It therefore acts to hold a train on the siding so long as a train is on the block beyond C and coming toward C, or at least to warn the train on the siding of the approaching train, according as the signal d' be made "cautionary" or "danger." The signal d' is not, however, to be regarded as a necessary element of my system, since on most sidings the engineer of a train on the siding and about to come onto the main track could, by turning around in his seat, see signals c^2 and c^3, which would show the condition of the block beyond C as plainly as signal d'. In particular localities, however, especially where the road has many curves and the signals are therefore likely to be hidden, the signal d' is of value. If desired it may be placed in a separate circuit having a battery of its own and passing through contact-points in the governor at the station beyond C, so that it will not be set to "danger" until the train is very near to C.

Passing now to Figs. 2 and 3, when a train going in the direction from E to F passes station E it sets signals e' and e^2 to "danger," causes the armature of governor e' to fall, thereby setting to "danger" signal f^6 and causing the armature of relay f'''' to fall, thereby setting to "danger" signals f^5, i^6, i^5, and i^4 and warning trains at station I to proceed with caution. When the train reaches station F, should it pass on over the main track it will cause the armature of governor f' to fall, setting to "danger" signals f', f^2, and siding-signal h', but not affecting signals f^3 and i^2. When the train has passed completely over track-instrument f, the circuit through contacts cf and of' is completed for an instant and the armature of governor e' raised, thereby restoring to "safety" signals e', e^2, and f^6 and raising the armature of relay f'''', thereby restoring to "safety" signal f^5. The raising of the armature of relay f'''', however, has no effect on signals i^6, i^5, and i^4, since their circuit passes through a contact of the governor f' between points 41 and 36, and as the armature of this governor is down the contact is broken. When the train reaches station I, it breaks contact ci', causing the armature of governor i' to fall, and thereby setting to "danger" signals f^3, i^2, k^6, k^5, and k^4. When it has passed completely over the track-instrument, a dotted circuit through contact-points oi' is completed for an instant, as follows: from the positive pole of battery 61 through contact-points ci to 62, through the rail to 63, to 64, to 65, through the main-track rail to 56 at station F, to 45, to 46, through the rail to 47, to 48, to 67, through the magnet-coils of governor f' to 60, through the track-rail to 68 at station I, through contact oi', and back to battery. The raising of the armature of governor f' restores to "safety" signals i^6, i^5, and i^4. When the train reaches K, signals k' and k^2 and the front signals in the block beyond are set to "danger," and when the train has passed station K the armature of the governor i' is raised, restoring to "safety" signals f', f^2, f^3, i^2, k^6, k^5, and k^4. Should the train go on to the siding at station F instead of continuing on over the main track, then when the train has passed off from the insulated section of track on the siding the dotted-line circuit, which is completed through contact-points og', but which is short-circuited so long as wheels are on the insulated sections, energizes the magnet of governor e', raising the armature and restoring to "safety" signals e', e^2, f^6, f^5, i^6, i^5, and i^4. When the train passes off from the siding at station I, the contact ch' is broken, setting to "danger" signals f', f^2, f^3, i^2, k^6, k^5, and k^4.

The function of signal f^3, which has not been heretofore apparent, is to protect a train on the siding and about to pass on to the main track from another train on the main track and going in the same direction. Suppose, for instance, that a train is on the siding and is about to pass on to the main track at station I. Suppose, also, that there is another train between stations E and F going toward F. When the first train passes on to the main track it sets to "danger," as rear signals, signals f', f^2, f^3, and i^2. When the second train reaches station F the engineer first sees signal f' at "danger" and checks the speed of his train. When he reaches signal f^2 and finds that also at "danger" he checks the speed of his train still further, and the same is true with respect to signal f^3, and he must either stop or proceed very slowly when he passes either or both of these signals at "danger," because these signals being at "danger" indicate that a train is within the block F I or else the block I K; but suppose that when he reaches signal f' he finds this at "safety" and proceeds at full speed, and finding signal f^2 also at "safety" still proceeds, he will see signal f^2 go to "danger" when the train passes over the track-instrument f and will know that the signal has been set by his train, but signal f^3 will not be set by his train, and should he see that signal go to "danger" he will know that a train has passed on to track-instrument h at the other end of the siding and perhaps on to the main track, or that a train has entered the block I K at K, and in either case he must bring his train under control at once and stop before reaching home-signal i^2. When the second train passed station F it set to "danger" siding-signal h', and this would act to hold the first train on the siding if the engineer of that train had not passed beyond the siding-signal; but in no case can accident occur, since the second train will move so slowly that if it comes up with the first train as it is leaving the siding it can be stopped at once.

The operation of the signals for trains going in the direction from K to E is precisely the same as that just described, the signals and circuits on the left side of the track corresponding in every respect with the signals and circuits on the right side of the track.

There are evidently many possible train movements which have not been described which may take place when two or more trains are between stations E and K and going in the same or different directions, or changing their direction of motion frequently, as when switching is going on, but the signals will show correctly the condition of the track for every movement of the trains without confusion.

It is usually impracticable at situations like that which has been here considered to adhere strictly to the absolute block-system, since in switching it may be necessary for trains going in opposite directions to approach each other quite closely; but since the trains must always move very slowly and carefully under such circumstances no accident can result so long as each train is kept aware of the presence of the other.

As I have said, the arrangement of signals shown in Figs. 2 and 3 may, under certain circumstances, be modified in order to better accord with the conditions affecting their location and operation. The desirability of such modifications arises from the length of the sidings, the traffic of the road, and from whether its switch-signals are interlocking or not. The illustration given in Figs. 2 and 3 supposes a double-point siding of about half a mile in length, which is not equipped with interlocking signals. In applying my system to a double-point siding equipped with interlocking signals it is obvious that the signals g' and h' may be dispensed with, if desired, and that the signals i^6 and f^3, which are special front signals, may be placed in the circuits in which signals g' and h' are shown instead of in the same circuit with the signals f^5 and i^2. The signals i^6 and f^3 in this case may be either danger or cautionary signals, as desired. It is further obvious that the signals g' and h' may be retained in this arrangement, if desired, so that signals g' and f^3 and h' and i^6 will be in the circuits respectively within which the signals g' and h' are shown in Figs. 2 and 3.

It is obvious that in the case of a very short double-point siding the signals i^5 and f^2 may be omitted, and likewise the signals i^6 and f^3, and that the circuits shown in the figures in which the signals g' and h' are may be broken by the front relays f'''' and i'', respectively. It is likewise obvious that where the siding is very long the signals i^4 and i^5 can be placed in a branch circuit from the closed-circuit battery at station I, instead of being, as shown, in a branch circuit from the closed-circuit-battery at station F, and that their mates, signals f' and f^2, may be in a branch circuit from battery 30 at station F, instead of being, as shown, in a branch circuit from the closed-circuit battery at station I, in which case the signals i^4 and i^5 will not be corresponding cautionary or distant signals of signal f^5, and the same is true of their mates f' and f^2 relatively to signal i^2. In this case the signals i^4, i^5, and i^6 will not be operated as front signals by the circuit-operating signals f^6 and f^5 as front signals, and the same is true for their mates for the opposite direction, but will be operated as front signals solely by circuits corresponding to those operating signals g' and h' in the figures. The home-signals f^5 and i^2 may in this case be equipped in the usual manner with corresponding cautionary signals.

Where a single-point siding is provided with interlocking signals, the special siding-signal may be dispensed with, if desired.

Referring now to Figs. 4, 5, 6, and 7, which, as before stated, show my signal system applied to a double-track railway, Fig. 4 shows the simple case of a double-track railway uncomplicated by sidings, crossovers, &c. It shows three signal-stations L, M, and N. x and y are the rails of the right track, traffic over which is in the direction from L to N. x' and y' are the rails of the left track, traffic over which is in the direction from N to L. Each track has its own signals, track-instruments, governors, and circuits, which are in no way connected with each other, except at crossovers, as will be hereinafter seen. Since travel is in one direction only over each track, it is not necessary to provide front signals or to divide the track into "signal divisions," all of the signals being rear signals, except at the crossovers. There is, therefore, no occasion for the use of the dashed-line circuits of the single-track system and of the relays which they control, nor for the special front signals. The circuits which are necessary are the full-line local circuits and the dotted-line or clearing circuits, and all of these circuits are much simplified. Since, however, it will sometimes happen that a train, after passing a signal-station and setting the signals there to "danger," will be required to back again, it is necessary to provide the track-instrument with contact-points for returning the signals to "safety" when the train backs past them and to connect the dotted-line circuits with these contact-points, as in the single-track system. Considering, first, the signals and circuits of the right track and beginning at station L, l', and l^2 are respectively distant and home signals for this station, and l' is the governor. l_1 is the track-instrument, and cl' is a normally-closed contact of the track-instrument, which controls the signal-circuit. 70 is the closed-circuit battery, which supplies current to the signal-magnets. The full-line circuit runs from the positive pole of battery 70 through contact-points cl' to the magnet-coils of governor l', thence through the upper armature-contact of the governor to signal l^2, thence to signal l', and thence back to the negative pole of the battery. This circuit, it will be seen, will be broken when the contact-points cl' are separated by the passage of a train over the track-instrument, thus setting to "danger" signals l' and l^2. It will be noted that signals l' and l' are connected in series. Under some circumstances this may be desirable, and for that reason I have shown such a method of connection for the signals. In general, however, I prefer to connect the signals in multiple, and this method of connection is shown at signal-stations M and N and in the succeeding figures. Passing now to station M, m' and m^2 are respectively distant and home signals, and m' is the governor. cm' is the normally-closed contact of the track-instrument, which controls the signal-circuits. 71 is the signal-battery. The full-line circuit runs as follows: from the positive pole of battery 71 through contact cm' to 72, where the circuit divides, one branch going through the magnet-coils of the governor m' and thence through the second upper armature-contact of the governor to 74, and thence back to the negative pole of the battery. The other branch from 72 goes through the first armature-contact of the governor and thence to 73, where it divides, one branch going through signal m^2 to 74 and thence back to battery 71. The other branch from 73 goes through signal-magnet m^1 and thence back to 74 and to the battery 71, thus placing the two signals in multiple. The full-line circuits of station N are the same as those of station M. Considering now the dotted-line circuits, and beginning at station M, om' and om'' are normally-open contacts of the track-instrument, om' being closed by a train going from M to N, while om'' is closed by a train going from N to M. cm_1 is a normally-closed contact in series with the normally-open contacts just mentioned, its function being the same as that of the corresponding contacts in the single-track system—viz., to prevent the closing of the dotted-line circuits when the train first passes upon the track-instrument and until the train has passed completely over the track-instrument. 75 is an open-circuit battery in circuit with the dotted-line circuits. The circuit runs from the positive pole of the battery 75 through contact om' to an insulated section of the left rail at 76, through the rail to 77, thence to 78 at station L, through the magnet-coils of governor l' and through the lower armature-contact of the governor if the armature be down to 79, thence by return-wire to 80, to 81, through an insulated section of the right rail to 82, and thence through contact cm_1 to the negative pole of the battery. Another circuit runs from the positive pole of battery 75 through contact-points om'' to an insulated section of the left rail at 83, through the rail to 84, thence through the magnet-coils of governor m' and through the second lower armature-contact of the governor if the armature be down, to 81, through the rail to 82, and thence through contact cm' to the negative pole of the battery. The dotted-line circuits at stations L and N are the same as those at station M. The operation of the circuits shown in this figure is as follows: Suppose a train on the right track to pass signal-station L. When the first wheel passes over track-instrument l_1 contact cl' is broken, causing the armature of governor l' to fall and setting to "danger" signals l^1 and l^2 as danger-signals. Contact cl_1 is also broken, and an instant after contact ol' closed. When the train has completely passed over the track-instrument, contact cl_1 is closed for an instant before contact ol' is broken, and a dotted-line circuit is completed for clearing the signals at the signal-station next behind L. Contact cl' is also closed; but, since the armature of governor l' is down, the signals l^1 and l^2 remain at "danger." When the train reaches station M signals m^1 and m^2 are set to "danger" and the armature of governor m' falls. When the train has completely passed over the track-instrument, contact cm is closed an instant before contact om' is broken, thus completing a circuit from battery 75 through contact-points om' to 76, to 77, to 78, through the magnet-coils of governor l' to 79, to 80, to 81, to 82, and through contact cm_1 back to battery. The armature of governor l' is therefore raised, re-establishing the full-line circuit through its magnet-coils and restoring to "safety" signals l' and l^2. In the same manner when the train reaches N signals n^1 and n^2 will be set to "danger" and signals m^1 and m^2 restored to "safety." Should the train, after passing M, back past it again, then when the train has completely passed over the track-instrument, a circuit will be completed from battery 75 through contact-points om'' to 83, to 84, through the magnet-coils of governor m^1 to 81, to 82, and through contact cm_1 to battery again. By this means signals m^1 and m^2 are restored to "safety."

It will be seen, as heretofore stated, that the circuits of the double-track system of signals are in effect the circuits of the single-track system simplified by the removal of all the circuits which have to do with the operation of the front signals. The circuits of the left track are exactly the same as those of the right track, and their operation is the same and need not be described.

Figs. 5, 6, and 7, as previously stated, show my system of signals applied to double-track crossovers. Fig. 5 shows the case of a crossover where the two parallel tracks which it connects are so far apart that it is possible to place a track-instrument with its insulated sections of track on the crossover-track, while Figs. 6 and 7 show the case where the two parallel tracks are placed too close together to permit of placing a track-instrument on the crossover-track.

Taking first the first-mentioned crossover (shown in Fig. 5) P and R are signal-stations on the right and left tracks, respectively, at the beginning and end of the crossover-track. Signal-station O of the right track is an advance signal-station, as is S of the left track, while O of the left track and S of the right track are signal-stations of the ordinary character. The full-line circuits at station O of the right track are similar to those of the ordinary double-track signal-station, except that since trains coming from the crossover are frequently liable to be on the block O P, it becomes necessary to provide means for setting signals o^1 and o^2 to "danger" as front signals for the train from the crossover, and hence the relay o'' is provided and the signal-circuit is passed through the armature-contact of this relay. The dotted-line circuits are the same as usual. A dashed-line circuit passes through the armature-contact of governor o', and this circuit will be considered hereinafter. At station P the full-line circuits are as follows: Taking first the right side of the track the circuit runs from the positive pole of battery 90 through the normally-closed contact-points cp' to 91, where the circuit divides, one branch going through the first armature-contact of the governor p', through the magnet-coils of the governor, and through the third upper armature-contact of the governor to 92, and thence back to the negative pole of the battery. The other branch from 91 goes through the second armature-contact of the governor to 93, where it divides, a branch going through each of the signals p^1 and p^2, the two branches uniting with the battery return-wire at 92. On the left side of the track the circuit goes from the positive pole of battery 90 through contact cp'' of track-instrument p, through contact cq'' of track-instrument q, on the crossover-track, and thence through the second armature-contact of governor p'' to 94, through the magnet-coils of the governor, and through the fourth upper armature-contact to the negative pole of battery 90. The dotted-line circuits at P are as follows: Taking first the circuit on the right side of the track, the circuit runs from the positive pole of open circuit-battery 95 to the normally-open contact-points op' of the track-instrument, thence on the left side of the track to 96, to an insulated section of the left rail at 97, through the rail to 98, thence to 99, where the circuit branches, one branch going to 100, thence to 101 at station O, thence through the magnet-coils of governor o', and through the third lower armature-contact, if the armature be down to 102, and thence over a return-wire to 103 to an insulated section of the right rail at 104 to 105, and through the contact cp of the track-instrument to the negative pole of battery 95. The other branch from 99 goes to 94, thence through the magnet-coils of the governor p'' and through the fourth lower armature-contact, if the armature be down, to the return-wire at 107, and so back to battery. Another circuit goes from the positive pole of battery 95 to 107, where it divides, one branch going to the normally-open contact-points oq' of track-instrument q, thence to an insulated section of the left crossover-rail at 108, through the rail to 109, and thence to 96, thus placing contact-points op' and oq' in multiple. The other branch from 107 goes to the normally-open contact op'', thence to an insulated section of the left rail at 110 through the rail to 111, to 112, and thence through the magnet-coils of governor p' and through the third lower armature-contact, if the armature be down, to the return-wire at 106. The right crossover-rail has an insulated section, and this is connected at 113 with a wire leading to contact cp and thence to the negative pole of battery 95. A dashed-line circuit begins at the positive pole of battery 113, station O, goes through the first armature contact of governor o' to 114, one branch going through signal p^5, the other through signal p^4 and through the third armature-contact of governor p'', the two branches uniting at 115, thus placing the signals in multiple and going back to the negative pole of battery 113 at station O. It will be seen that while both signals p^4 and p^5 will be set to "danger" by the fall of the armature of governor o', the fall of the armature of governor p'' affects only signal p^4. Another circuit begins at the positive pole of battery 116, station P, goes through the first contact of governor p'' to signal o^3 and through the magnet-coils of relay o'' to the negative pole of battery 116. The circuits of the left track are in all respects the same as those described for the right track, and need not be further described. In the circuits of the right track I have shown no insulated sections of rails nor any electrical connections therefor, though they are supposed to be and must be there. My reason for this is to make clear the distinction between the circuits which properly belong to the signaling system itself, and the circuits which belong to and form a part of the track-instrument. It has been convenient in the description of the system to describe and show fully the insulated sections of track and their operation in order to make it clear that there are no possible train movements which can cause an incorrect operation of the signals, though the insulated sections of track and their electrical connections by which they are enabled to short-circuit the battery when the train is standing over the track-instrument are properly a part of the track-instrument. On the left track in this figure, therefore, I have shown only the circuits which properly are elements of the system, in order to make the distinction clear. The operation of these crossover-circuits is as follows: Suppose a train on the right track and going in the direction O P to pass station O. When it passes over track-instrument o it sets to "danger" signals o^1 and o^2, and by the falling of the armature of governor o' sets to "danger" signals p^4 and p^5. It likewise clears the signals at the signal-station next behind O. When the train passes on to the signal-station P, if it passes on over the main track it sets to "danger" signals p^1 and p^2, and by completing the dotted-line circuit through contact-points op', raises the armature of governor o', thereby returning to "safety" signals o^1, o^2, p^4, and p^5. If, however, the train goes on to the crossover-track, it breaks contact cq' of crossover track-instrument q, causing the armature of governor r'' to fall and setting to "danger" signals r^1 s^6, and through the fall of the armature of relay S'''', signals s^4 and s^5. Should the engineer, before passing over track-instrument q, (see signal r^1,) already at "danger," he must either stop or else proceed with great caution; but should he see signal r^2 also at "danger" he must stop, since special front signal r^2 indicates that a train is approaching from S, while r^1 only being at "danger" indicates that a train has passed beyond r^1 toward S. Should signal r^1 be at "safety" until the passage of his train over track-instrument q sets it to "danger," he is assured by the setting to "danger" of signal r^1 that he is protected in front by front signals at station S, and since signal r^2 is not set to "danger" by the fall of the armature of governor r'' he may proceed on over the left track. When the train has passed completely over track-instrument q, the circuit through contact-points oq' is completed for an instant, and as this circuit is in multiple with contact-points op' the effect on the signals is the same as though contact-points op' had been closed, and the armature of governor o' is raised, restoring to "safety" signals o^1, o^2, p^5, and p^4. When the train has passed over either of track-instruments s or r in its movement on the left track, signals r^1, s^6, s^5, and s^4 will be restored to "safety." Signals p^4 and r^1 should be so located that they may be seen by the engineer of a train passing over the crossover-track before he has passed over track-instrument q, so that should he find the signal ahead of him already at "danger" he will be warned that another train is only a short distance ahead of him, and he will then proceed, if at all, with great caution.

The operation of the signals for trains going from the left track to the right track is exactly the same as that just described and needs no further description.

Where the crossover-track is of considerable length there may be two track-instruments on it, one near each end, and a train passing over the crossover will clear the rear signals when it has passed completely over the first track-instrument, but will not set any signals to "danger" until it has reached the second track-instrument.

When the crossover-track is of very great length and is much hidden by curves, trees, or the like, it may be provided with a single-track system of signals of its own, quite independent of the signals of the main tracks.

Figs. 6 and 7, as previously stated, show the signal arrangements for a very short crossover. Fig. 7 is an enlarged detail of Fig. 6, showing only the two signal-stations U and V at the end of the crossover-track. T of the right track and W of the left track, corresponding to O and S of Fig. 5, respectively, are advance signal-stations, and their circuits do not differ from those of stations O and S. Signal-station T of the left track and W of the right track are the ordinary double-track signal-stations.

Since Fig. 7 shows most clearly the connections at stations U and V, which stations are the ones most to be considered, most of the description of the circuits will refer to that figure alone. The signals of this crossover are similar in function and are similarly located to those of the crossover shown in Fig. 5; but since there is no track-instrument on the crossover it is necessary to have at each end of the crossover and operated by the switch which closes and opens the crossover-track a switch-instrument of any approved pattern, these switch-instruments being diagrammatically shown in Figs. 6 and 7 and lettered u_1 and v_1. Taking up first the full-line circuits and beginning at station U, the circuit runs from the positive pole of battery 120 to 121, where it divides, one branch going through the normally-closed contact cu' of track-instrument u to 122, where it again divides, one branch going through the first armature-contact of governor u', through the magnet-coils of the governor, then through the third upper armature-contact to 123, and then to the negative pole of battery 120. Another branch from 122 goes through the second armature-contact of governor u' to 124, where it divides, a branch going through each of the signals u^1 and u^2, the two branches uniting at 125, thus placing the signals in multiple and going to 123, and thence to the negative pole of battery 120. A third branch from 122 goes to the contact 126 of switch-instrument u_1, which contact is broken when the crossover-switch is closed, and through that to the conductor from battery 120, thus serving to short-circuit the contact cu' when the crossover-track is open. The other branch from 121 goes through normally-closed contact cu'' to 127, where it divides, one branch going through the second armature-contact of governor u'', through the magnet-coils of the governor to the fourth upper armature-contact, and through that to 128 at station V, thence through the normally-closed contact cv''' of track-instrument v to 129, where it divides, one branch going to the negative pole of battery 120 at station U, the other branch going through contact 130 of switch-instrument v_1 to 128, thus short-circuiting the contact-points cv''' when the contact 130 is closed, which is always the case when the left track is clear and the crossover is closed to trains on that track. The other branch from 127, station U, goes to the contact 131 of switch-instrument u, which is normally open, and through that to the conductor from the positive pole of battery 120, thus serving to short-circuit contact cu'' when the crossover-switch is thrown open. The full-line circuit running through contact cu''' of track-instrument u corresponds to the circuit just described as running from the fourth armature-contact of governor u'' through contact cv''' of track-instrument v and back to battery 120, and need not be further described. The dotted-line circuits are as follows: Commencing at the positive pole of battery 132, one circuit runs through contact 133 of switch-instrument u_1, and through track-instrument contact cu_1, where the circuit divides, one branch going through normally-open track-instrument contact-points ou' to 134, where the circuit again divides, one branch going to an insulated section of the left rail at 135, through the rail to 136, to 148 at station T, (see Fig. 6,) through the magnet coils of governor t', and through the third lower armature-contact of the governor, if the armature be down, to 137, and back by return-wire to 138, Fig. 7, to 139, through an insulated section of the right rail to 140, and back to the negative pole of the battery. The other branch from 134 goes through the contact 141 of switch-instrument v_1, which contact is broken normally, and through the track-instrument contacts cv_2 and ov'''' to an insulated section of the right rail of the left track at 142, through the rail to 143, and thence to the positive pole of battery 132, the object of this branch being to permit a train when passing from the crossover to the left track to raise the armature of governor t', and so to clear its rear signals. Another branch of the dotted-line circuit goes from the negative pole of battery 132, and through the normally-open contact 144 of the switch-instrument v_1 and the normally-open contact ov''' of the track-instrument v to an insulated section of the left rail at 145, thus short-circuiting the battery through the wheels of the train, should the train stop over the track-instrument, and thus by operating the track-instrument contact-points should cause the dotted-line circuit to be closed momentarily. The other branch from contact cu_1 goes through normally-open track-instrument contact ou'' to 149, thence through the contact 150 of switch-instrument u_1 to 151, thence through the magnet-coils of governor u' and through the third lower armature-contact, if the armature be down, to the return-wire at 152, and so back to battery. A branch circuit from 151 leads to the track-instrument contacts ow' at station W, and serves to raise the armature of governor u' when a train passes station W. All of the dotted-line circuits of station V are mates of corresponding circuits of station U, already described, and need no further mention. All the dashed-line circuits of this crossover are the same as those of the crossover shown in Fig. 5, and need not be again described. It will be observed that the track-instruments at stations U and V have many more contact-points than the track-instruments at the ordinary signal-stations. Taking the track-instrument at station U as an example, on the right side of the track it has, besides the usual normally-closed contact cu', another normally-closed contact cu''', which is, however, cut out by a branch circuit passing through the switch-instrument, unless the switch is thrown to allow a train to go on to the crossover-track, in which case contact cu' is short-circuited by the switch-instrument, so that contact cu' is effective to break its circuit only when the train is to pass on over the main track, while contact cu''' is effective only when the train is to pass on over the crossover-track. On the left side of the track there are, besides the usual normally-open contact ou'', two other normally-open contacts ou''' and ou'''', the contact-points of which are preferably carried by the same contact-levers, since the same circuit passes through both contacts, and it is very important that they act exactly simultaneously. The track-instrument has also two normally-closed contacts cu_1 and cu_2 in circuit with the dotted-line circuits, where the ordinary track-instrument has only one. These contacts are operated by the same means, however, and act simultaneously. The operation of these crossover-circuits is as follows: Suppose a train on the right track to pass station T. When it passes over the track-instrument t, it sets to "danger" as rear signals, signals t^1 and t^2 and as front signals, signals u^4 and u^5. When the train reaches station U, if it passes on over the main track, it causes contact-point cu' to separate, setting to "danger" signals u^1 and u^2 and causing the armature of governor u' to fall. Contact-points cu''' are also separated; but since they are short-circuited through a contact of the switch-instrument u_1 their separation has no effect. When the train has passed completely over the track-instrument, the dodted-line circuit is closed for an instant through contact-points cu_1 and ou', and the armature of governor t' at station T is thereby raised, restoring to "safety" signals t^1 and t^2 and u^1 and u^5. When the train passes station W, the contact ow' is closed, raising the armature of governor u' and restoring to "safety" signals u^1 and u^2. If instead of going on over the main track the train goes on to the crossover at U, then switch-instruments u_1 and v_1 are operated by the throwing of the switches to permit the train to enter and leave the crossover-track. Operating the switch-instrument u_1 breaks the contact through which track-instrument contact cu''' is short-circuited and short-circuits contact cu' through contact 126 and contact cu'' through contact 131, thus rendering both ineffective to break their circuits, so long as the crossover-track is open. The breaking of contact cu''' now breaks the circuit of governor v'', causing the armature to fall and setting to "danger" signal v^1 and the signals w^4, w^5, and w^6 at station W. The dotted-line circuit through contact ou' of the track-instrument, for clearing the signals at station T, is now broken at contact 133 of switch-instrument u_1, and therefore the closing of contact ou' does not operate to clear the signals at station T. When a train has passed over the track-instrument v, contact cv_2 is closed and the dotted-line circuit from battery 132 through contacts cv_2 and ov'''' to 134 and governor t' is completed for an instant, thus raising the armature of governor t' and restoring to "safety" signals t^1, t^2, u^4, and u^5. Should the engineer find signal v^1 at "danger" before he reaches it, he is warned that a train going toward W has passed the signal ahead of him, and he will then stop or proceed with great caution; but in no case will he proceed if he finds signal v^2 also at "danger." Should the signal v^1 be at "safety" until it is set to "danger" by his own train, he is assured by the setting to "danger" of signal v^1 that the signals are in working order and that his front signals are set, and he can then proceed over the left track to station W or can go back to station V and beyond over the main track, in either case signals v^1 and the front signals at station W being returned to "safety" when the train passes over the track-instrument at either of the stations named. Supposing now that a train has passed from station T to station U on the right track and has passed beyond station U, setting to "danger" signals u^1 and u^2 and causing the armature of governor u' to fall, and that a train comes from the left track over the crossover-track to the right track, this second train sets to "danger" signals u^4, t^1, t^2, and t^3, and when it has passed over the track-instrument u restores to "safety" signals v^1, v^2, w^4, and w^5, which it set to "danger" when it passed station W, through the simultaneous closing of contacts ou''', ou'''', and cu_2. The simultaneous closing of contacts cu_1 and ou'' will not result in the raising of the armature of governor u' and the restoring to "safety" of signals u^1 and u^2, however, as would be the case had the train come from beyond U on the right track, since the circuit of contact cu_1 passes through contact 150 of the switch-instrument u_1 and this contact was broken when the switch was thrown to admit the train to the right track.

At double-track crossovers, as at sidings, it may sometimes, for the reasons already given, be desirable to arrange the signals somewhat differently from the way in which I have shown them arranged. When the crossover-tracks face oppositely from those which I have shown in the drawings, so that a train passing from one track to the other will enter the second track in the direction in which traffic ordinarily proceeds over that track, but will leave the first track in the direction opposite to that in which traffic ordinarily proceeds, the signals will have to be arranged analogously to the arrangement shown in Figs. 2 and 3, at a double-point siding, or to the arrangement shown in Fig. 1 for a single-point siding, since the conditions are substantially the same, as will be apparent if we assume for the moment that the main track, which the train is leaving, is merely a siding branching from the main track which the train is entering; but it will be observed that the arrangements of the governors shown in the drawings will be the same in either case, and that it is such that any number of signals required may be operated by them in any order required, so as to accord with the conditions of traffic, whatever these may be.

In cases where the blocks composing a signal-division are very long, or where a signal-division is composed of a large number of blocks, it may be desirable, in order to reduce line-leakage as far as possible, and thereby save a useless waste of battery power, to have a separate dashed-line-circuit battery for each direction in every block, in place of having one battery for each direction for several blocks, or for every signal-division. A slight modification of the dashed-line circuits is all that is necessary to accomplish this result. This modification I have illustrated in Fig. 8, in which A B is a block corresponding to the block A B in Fig. 1; a and b, the track-instruments; a', b', and b''', the governors; a'', b'', and b'''', the front relays, which, with the exception of the terminal relay a'', are provided with two sets of contact-points. 160, 161, and 162 are the dashed-line-circuit batteries; and a^3, b^3, and b^6 are the special front signals. Only the dashed-line circuits are shown in this figure, as the other circuits are unaffected by the change made in the dashed-line circuits. The circuit from battery 160 passes through the first contact of governor a' through the magnet-coils of relay b'''', thence through signal b^6, and back to battery. The circuit from battery 162 passes through the second contact of relay b'''', thence through the first contact of governor b', and thence through the front relay and special front signal in the block beyond B and back to battery. The circuit of battery 161 passes through the first contact of governor b''' and through the second contact or relay b'' to the magnet-coils of relay a'', and thence through the special front signal a^3 back to battery. It will be seen that the effect on the circuit of battery 162 is the same, whether the armature of governor b' or relay b'''' is down, so that the front signals are set throughout the division just as they are with the arrangement of circuits shown in Fig. 1. The full-line-signal circuit passes through the first contact of the front relay at each station, as in Fig. 1.

The operation of the arrangement of circuits shown in Fig. 8 is as follows: A train moving from A toward B passes over the track-instrument a and causes the armature of governor a' to fall, thus breaking the circuit of battery 160, and thereby setting to "danger" signal b^6, and causing the armature of relay b'''' to fall. The fall of the armature of relay b'''' breaks the circuit of battery 162, thereby causing the armature of the front relay corresponding to b'''' at the station next beyond B to fall, and setting to "danger" the special front signal at that station also. In this manner the armatures of all of the front relays in the division on the left side of the track are caused to fall, and all of the front signals on the left side of the track are set to "danger." When the train reaches station B and passes over track-instrument b, the armature of governor b' is lowered and the circuit of battery 162 broken in a second place by the breaking of the first contact of the governor, thus maintaining at "danger" the signals in front of the train. When the last wheel of the train has passed over track-instrument b, the armature of governor a' is restored to normal, completing the circuit of battery 160, thereby restoring to "safety" signal b^6, and raising the armature of relay b''''. The circuits of the remaining dashed-line-circuit batteries are completed in a similar manner as the train passes on over the division.

For economic and other reasons it is desirable to reduce the number of line-wires required in my system to a minimum, and I have therefore provided for the dashed-line circuits a modification utilizing some of the principles of duplex telegraphy, by means of which I am able to reduce the number of dashed-line-circuit line-wires to two, of which one is the return-wire. This modification is illustrated in Fig. 9, which shows only the dashed-line circuits, except at station A, where the full-line circuits are shown in order to make clear a slight modification, which is necessary where the dashed-line circuits are modified in the manner now to be described.

In employing the principles of duplex telegraphy in an automatic railway-signal system it is necessary that the apparatus should be so arranged that in case of leakage from the line-circuits, the signals, if affected at all by such leakage, will be set to "danger." On account of danger of leakage, I prefer not to employ the duplex arrangement except where the blocks are comparatively short or where very good insulation can be obtained. Under these circumstances I regard it as preferable, since it reduces the number of line-wires ordinarily required from six to four, and reduces the number to two where the rails are used as conductors of the dotted-line circuits from station to station, as in my permissive block-system, hereinbefore described. It is further necessary, in order to make the safety-factor as high as possible, that the apparatus be so arranged that the breaking of the line-wire at any point within the block, or a great increase in its resistance, due to a faulty joint or other cause, will cause the signals at each end of the block to go to "danger," and that the failure of the apparatus to work properly shall cause the signals to indicate "danger." The arrangement here shown is designed to meet these requirements.

Referring now to Fig. 9, A B is a block corresponding to the block A B of Fig. 1. a', b', and b''' are the governors, a and b the track instruments at stations A and B, respectively, and a'', b'', and b'''' are the front relays, which in this case are differentially-wound polar relays. a^4 and a^5 are relays of the ordinary type, which I will term "special" safety-relays, the function of which is to set the signals at each end of the block to "danger," in case of breakage of the line-wire or great increase in its resistance. a^2 and a^3 are respectively the home and special front signal at station A; ca', the normally-closed contact-points of track-instrument a. 163 is the full-line circuit-battery at station A. 164, 165, and 166 are dashed-line-circuit batteries, and 167, 168, and 169 are resistance-coils. At station A, I have shown how the signals are connected where this modification is used, the special front signal being in a branch circuit from the local closed circuit-battery 163, an arrangement which may be employed in the other methods of operating the signals, if desired. I have not shown the local signal-circuits at the other end of the block, since they are precisely the same, except for the addition of branch circuits for operating the distant signals, as in Fig. 1. The circuit of battery 163 runs from the positive pole of the battery to 170, where it divides, one branch going to signal a^3 and thence to 171, through the contact of relays a^4 and a'' to 172, and so back to battery. The other branch from 170 goes through the contact ca' to 173, where it divides, one branch going through signal a^2 and the third contact of governor a' to 171, and so back to battery. The other branch from 173 goes through the magnet-coils of governor a' and through the fourth contact of the governor to 172, and so back to battery. It will be seen that the common return-wire of the two signals passes through the contacts of relays a^4 and a'', so that when the armature of either of these relays is down both signals will be set to "danger." The fall of the armature of the governor a', however, only affects signal a^2 at station A. The dashed-line circuits are as follows: Beginning at battery 164 the circuit runs from the positive pole of the battery through the first contact of the governor, if the governor-armature be up, to the second contact-point carried by the armature of the governor, where it divides, one branch going through the upper coil of relay a'', thence through the coils of relay a^4 to 175 at station B, thence through the coils of relay a^5, thence through the upper coil of relay b'''', through the second contact of governor b''', thence through the lower coil of relay b'''', through resistance-coil 168 to the return-wire at 176, and so back to battery. The other branch from the second contact carried by the armature of governor a' passes through the upper second contact of the governor through the lower coil of relay a'', thence through the resistance-coil 167 to 177, and so back to battery. Considering now the circuits of battery 165 at station B, the circuit runs from the positive pole of the battery through the second contact of the relay b'', if the armature of the relay be up, thence through the first contact of governor b''', if the armature of the governor be up, to the second contact-point carried by the armature of the governor, where it divides, one branch going through the upper coil of relay b'''', thence through the coils of relay a^5 to 175, thence through the coils of relay a^4 at station A, thence through the upper coil of relay a'', through the second contact of governor a', thence through the lower coil of relay a'', through the resistance-coil 167 to 177, thence to 176, and so back to battery. The other branch from the second contact carried by the armature of governor b''' passes through the upper second contact of the governor through the lower coil of relay b'''', thence through the resistance-coil 168, and back to battery. It will be observed that the batteries 164 and 165 are of unequal strength, the object of this being to maintain a current through the coils of relays a^4 and a^5, and so energize the magnets of the relays when the circuits of both batteries are closed and are consequently opposed to each other, since, were their strength equal, no current would flow through relays a^4 and a^5, and consequently their armatures would drop so as to set the signals at both ends of the block to "danger." The permanent polarity of each front relay is such that current coming in from the line passing through its coils tends to cause the armature to be repulsed from the lower pole of the magnet and to be attracted to the upper pole. The adjustment is such, however, as shown in the drawings, that if no current at all passes through the relay-coils, or if two currents passing in opposite directions through the coils neutralize each other, the armature will be nearer the lower pole than the upper pole of the magnet, thereby being attracted by the lower pole and breaking the contacts of the relay, which are closed when the armature is up. A small spring or weight may be provided to aid in causing the armature to fall to the lower pole, if desired. Likewise, if the outgoing current passing through the upper relay-coil is greater than the current passing through the lower coil the armature will be repulsed by the upper and attracted by the lower pole with the same result; but it will be seen that if the current passing through the lower coil is greater than that passing through the upper it will tend to cause, and if sufficiently great, will cause, the armature to be repulsed from the lower and attracted to the upper pole. It will be apparent that with this arrangement any decrease in the normal line-resistance will tend to cause the armature to approach the lower and any increase in the line-resistance will tend to cause it to approach the upper pole of the relay, since in the former case more current from the home battery will pass through the upper coil than through the lower and in the latter more will pass through the lower than through the upper. Each resistance-coil has a resistance which, added to the resistance of the lower coil of the relay to which it is connected, is equal to the sum of the resistances of the other branch of the circuit when the governor-armature at the other end of the block is down, and consequently cuts out of circuit its corresponding resistance-coil and the lower coil of the front relay. Thus the resistance-coil 167 has a resistance which, added to the resistance of the lower coil of the relay a'', is equal to the resistance of the upper coil of the relay a'' plus the resistance of the relays a^4 and a^5, plus the resistance of the line-wire leading from the upper coil of relay a'' to the upper coil of relay b'''', plus the resistance of the upper coil of relay b'''', plus the resistance of the return-wire leading from the second lower contact of governor b''', (the armature of the governor being down,) to 177 at station A. The arrangement of circuits controlled by the governor b' is the same as that of the circuits controlled by governor b''', except that here the special safety-relays and the cut-out contact for the lower relay-coil and resistance-coil are omitted. This arrangement may be employed, if desired; but I prefer the arrangement comprising the special safety-relays and cut-out, since it insures that no accident can result from failure of the apparatus. It will be seen that the front relays at station B, as with all stations where this duplex method is used, except terminal stations like A, are provided with two sets of contact-points. One set of these contact-points serve to control the local signal-circuits, while the other set controls the circuit of the front relay of the station next ahead, as shown, in substantially the same manner that the governor does, so that any number of front blocks may have their signals operated by a single governor-armature being down. For instance, the armature of relay b'''' being down has the same effect on the front relay-circuits at and beyond station B that the armature of governor b' has when down. It will be apparent that the front relays may, if desired, be provided with contacts for controlling the circuits of the line-batteries exactly like those operated by the governors, so that the dropping of the armature of one of the front relays will cut out the lower relay-coil and resistance-coil instead of merely short-circuiting them, as shown; but usually this will not be necessary.

Before proceeding further it will be necessary to describe the action of the polarized relays as here arranged in circuit in case of line-leakage and of the special safety-relays and cut-out in case of a break in the line or a great increase in its resistance. Considering first the action of the polarized relays in case of line-leakage, we will suppose the armature of governor b''' to be down. The line-current from battery 164 will now pass through the upper coil of relay b'''', through the second lower contact of governor b''' to 179, thence to 176, and back to battery. Supposing now that the leakage of the line is such as to cause considerably more current from battery 164 to pass through the upper coil of relay a'' than passes through the lower coil, it is apparent that with an ordinary differential relay that is not polarized the excess of current passing through the upper coil will maintain the magnet energized, so that the armature will be attracted. Such is not the case with the arrangement here shown, however. The excess of current passing through the upper coil of the magnet causes the upper pole to repulse and the lower pole to attract the armature, and hence it drops to the "danger" position. If the line-leakage is sufficiently great, so that when the armature of governor b''' is up the excess of current passing from battery 164 through the upper coil of relay a'' overbalances the current from battery 165 and induces a stronger opposing polarity than the polarity induced by the combined effect of the current from battery 165 and that from battery 164, which passes through the lower coil, then the armature of the relay will drop into the "danger" position, and the same is true of relay b'''' and its corresponding connections. It will be seen, therefore, that the only effect of line-leakage, should it become of sufficient magnitude to affect the operation of the system, is to set the signals to "danger." Considering now the case of a break in the line and supposing the line to be broken at any point, it will be evident that no current can pass through the magnets of relays a^4 and a^5. Hence their armatures will drop and separate their contact-points, thereby setting the signals at each end of the block to "danger," since the signal-circuits, as has been described, pass through the contact-points of these relays; but it will be apparent that should a break occur in the line the front signals, upon the entrance of a train into a block, would be set to "danger" independently of these relays. Supposing the line should be broken, then the entire current from battery 164 will pass through the lower coil of relay a'', causing the armature to remain up, thereby holding the signals to "safety," if we suppose, for the moment, that the relays a^4 and a^5 are not in the system. Then, upon a train entering the block—for instance, A B at A—it would lower the armature of governor a', and thereby cut out the lower coil of relay a'' from the circuit of battery 164, so that the armature would be attracted to the lower pole of the magnet, and thereby set the signals a^2 and a^3 to "danger," and thus stop the train. It will be evident that should another train enter at B at the same moment it would have the same effect on relay b'''', and hence on the signals, so that ordinarily the signals would be set to "danger," so as to prevent trains passing beyond them into the block independently of the relays a^4 and a^5; but if we suppose a train to first enter the block A B at B, with the line-wire unbroken when it enters, so that the signals operate properly, the front signals at B remaining at "safety" and the front signals at A going to "danger," and then the line should break after the train has passed the front signal at B, it will be evident that without the relays a^4 and a^5 the signals at A would, upon the breaking of the line, return to "safety," so that a second train might enter at A at the same moment that the train within the block arrived at A, so that the two would come into collision. At the entrance of a block from a siding a collision resulting from a similar cause would be still more likely to occur, because in the case supposed the train approaching station A would probably be moving very slowly, since it would be very close to the terminal, and likewise the train entering at A would probably be moving slowly, since it is just starting out; but in the case of a train entering from a siding the train within the block may be supposed to be moving with full speed and to arrive at the end of it at practically the same time that the train on the siding enters it, so that a collision would inevitably result. The necessity of relays a^4 and a^5 will now be apparent, since by means of these the signals at both ends of the block must go to "danger" the instant the break in the line occurs. I have so arranged the connections that the lower coil of the front relay and the resistance-coil are cut out by the dropping of the home-governor armature instead of being merely short-circuited, as in systems of duplex telegraphy, and as shown on the right at station B. The object of this is as follows: Should electrical connection not be made between the second armature contact-point and its corresponding lower contact-point were the connections so that the lower coil of the relay and the resistance-coil would be merely short-circuited, as with the arrangement shown at the right, station B, then the armature of the governor, say at station A, being down, the resistance of the line-branch of the circuit of battery 165 at station

B would be so great that since its current must pass in that case not only over the line but through both coils of the relay a'' at station A and through the resistance-coil 167 the far greater portion of the current would pass through the lower coil of the relay and the resistance-coil at station B, so that the armature of relay b'''' would be held up thereby and the train lowering the governor-armature at A would not set signals at the other end of the block to "danger;" but with the arrangement shown, if electrical contact is not made or if a bad contact is made, which greatly increases the resistance when the governor-armature falls, then this is equivalent to a break in the line, so that the signals at both ends of the block will be set to "danger" by the current being cut out from the relays a^4 and a^5. The operation of these circuits is as follows: A train entering the block A B at A lowers the armature of governor a', thereby breaking the circuit of battery 164 through the separation of the first upper contact-point from the first armature contact-point, cutting out the lower coil of the relay a'' and the resistance-coil 167 through the separation of the contact between the second armature contact-point and second upper contact-point, and closing contact between the lower second contact-point of the governor and the second armature contact-point. Since the current which now passes through the upper coil of the relay a'' is the incoming line-current its armature is held in the normal or "safety" position; but since the current from battery 165 divides and passes in opposite directions through the coils of relay b'''', the currents passing through the coils of the magnet neutralize each other and the armature of the relay falls. The circuits (not shown in the figure) of the signals on the left side of the track at station B are thereby broken and the signals set to "danger." The circuit of battery 166 is likewise broken, thereby short-circuiting the lower coil of relay b'' and the resistance-coil 169, thus setting to "danger" the front signals at the station next beyond B, and causing the armature of the front relay there to fall, and so on throughout the division. When the train reaches station B and has entirely cleared the track-instrument, the armature of governor a' is raised through the action of the dotted-line circuits. (Not shown in the drawings.) The circuit of battery 164 is thereby completed, thus causing the armature of relay b'''' to rise and restore to "safety" the signals on the left side of the track at station B, which were set to "danger" when the armature of the relay dropped. Since the armature of governor b' is now down, however, the front signals at the remaining signal-stations within the division are still retained at "danger," the signals at each station being returned to "safety" as the train clears the track-instrument at that station. The operation of the circuits for the direction from B to A is the same in all respects as for the direction from A to B, and need not be described.

It will be seen that when the armatures of both governors a' and b''' are up the relays a^4 and a^5 are energized, so as to attract their armatures and maintain the signal-circuits completed by the current from battery 165, which is stronger than that of battery 164, and consequently sends sufficient current through the relays to energize them. When the armature of governor a' falls, the current from battery 165 still serves to energize these relays, and when the armature of governor b''' falls then the current from battery 164 energizes them, since it will then not be overbalanced by the current from battery 165, so that the armatures of these relays remain attracted so long as either or both batteries are sending a current over the line. In case, however, the armatures of both governors a' and b''' are down at the same time, then no current will be passing over the line and the armatures of these relays will be released, so as to separate their contact-points until one or both of the governor-armatures are returned to normal. Since when both governor-armatures are down the signals at each end of the block are set to "danger," it will be apparent that the separation of the contact-points of these relays when both governor-armatures are down can have no effect on the signal-circuits by breaking them, since they are independently broken by the front relays at each end of the block.

It will be seen that if a train should enter the distant end of the division at the same moment that a train enters the division at A each train will set to "danger" all the front signals that it would set if it entered alone, since when two trains enter the division at the same moment all of the dashed-line circuit-batteries are cut out, which has the same effect on the armatures of the front relays as in the case where only one train enters when the circuits of the batteries for one direction are cut out and the circuits of the batteries for the other direction made to neutralize each other.

It will be seen that the system of duplex telegraphy which I have modified and adapted to operate the front signals of my system, as herein described, is what is known as the "differential" duplex. It will, however, be apparent to those skilled in the art that what is known as the "bridge" system of duplex telegraphy may be adapted to operate the front signals of my system with equal facility and in substantially the same manner that I have shown them operated by my adaptation of the differential system, the governors in both cases merely taking the place of the "transmitters" employed in these systems of telegraphy. In case the bridge method be employed it will be necessary, in order to make the safety-factor as high as in the differential, to place one of the special safety-relays in each of the two arms of the bridge which are between the cross-wire and battery, as well as one at each end of the block in the line-arm; and the front relay, which is placed in the cross-wire, should be polarized, so that the outgoing current from the home battery, if it affects it at all, will tend to cause it to assume the "danger" position, the signal-circuits passing in series through the contact-points of all the special safety-relays and the front relay at each end of the block in the same manner that the signal-circuits at station A pass through the relays a^4 and a''. It will be obvious that in case of line-leakage, a break in the line, or a great increase in its resistance, the action of the apparatus will be substantially the same in the case of the bridge arrangement as with the differential.

In describing the operation of the apparatus illustrated in Fig. 9 I have stated that the resistance of the resistance-coils and the lower coils of the polarized relays should be equal to that of the line plus that of the line-instruments, (the governor-armature at the distant end of the block being down;) but it will be seen that the system will be operative, even though the resistance of the line and its connections be very much less than that of the resistance-coil and lower relay-coil or "artificial" line. The efficiency of the system in the use of battery-power will, however, be greatest when the resistances of the two branches are equal. It may in practice prove desirable to have the resistance of the artificial line somewhat greater than that of the line, so that in case of any small increase of resistance in the line the resistance of the coils will always at least equal it—as, for instance, the increased resistance of the line resulting from a faulty contact.

In Fig. 10, as before stated, I have shown a modified method for operating the special siding-signals at sidings. In Figs. 1, 2, and 3 I have shown the special siding-signals operated only by the regular governors of the system; but it will be evident that in some cases where the length of the block, at the end of which the siding is placed, is great and the governor at the distant end of the block from the siding is made to set the special siding-signal to "danger," a train standing on the siding might be unnecessarily held back by the entrance of a following train into the block at the distant end of the block before the train on the siding had passed on to the main track. Hence, it is sometimes desirable to have the siding-signal operated by a special track-instrument and governor of its own, located within the block at any desired distance from the siding, thereby causing the siding-signal to go to "danger" only when a train approaching the siding shall have gotten within a short distance of it. Likewise, where a double-point siding is very short it will be desirable, and indeed, necessary, to have the special siding-signal set to "danger" before the siding is reached, and maintained at "danger" until the siding is passed or until the train shall have passed onto the siding. Circuits meeting these requirements are illustrated in Fig. 10, one of the special siding-signals of the double-point siding there shown being provided with special means for causing it to be set to "danger" only when a train is near the siding. F and I are signal-stations at the ends of the siding, as in Figs. 2 and 3, and between them is the double-point siding-block previously described. E_1 is a point intermediate between station F and the distant signal-station E (not shown) preceding it. e_1 is the track-instrument at E_1; ce_1', its normally-closed contact-points; oe_1'', its normally-open contact-points; e_1', the governor for the special siding-signal h', and e_1'' is a special relay in circuit with the regular dotted-line circuit between stations E and F. Only those circuits are shown which are necessary for the comprehension of the manner in which the signal h' is operated. 180 is a closed-circuit battery at station E_1, which operates signal h'. Normally, the circuit of this battery passes through the line-wire from the positive pole of the battery to 181, thence through signal h' to the first contact of governor f', through that contact, if the armature of the governor be up, to the magnet-coils of governor e_1', thence to 182, through the contact of the governor to 183, to 184, and through contact-points ce_1' to the negative pole of battery 180. If the armature of governor f' is down the circuit of battery 180 is short-circuited through a wire leading from the lower first contact-point of the governor to 181, the signal h' being thereby cut out and set to "danger." Branch circuits lead from 182 through contact-points oe_1'' to 183, and from 182 through the contact of relay e_1'' (this contact being normally broken since the relay is in a normally-open circuit) to 184. The operation of these circuits is as follows: A train passing over track-instrument e_1 in the direction from E_1 to F separates the contact-points ce_1' of track-instrument e_1, thereby breaking the circuit of battery 180, causing the armature of governor e_1' to fall and setting to "danger" signal h'. When the armature of governor e_1' falls its contact-points are separated and the armature remains down until raised by the completion of a circuit through the coils of the governor-magnet independent of the contact-points of the governor. Should the train reverse its direction of movement and pass over the track-instrument in the direction from F to E_1, it will close the contact oe_1'', which will complete a circuit as follows: from the positive pole of battery 180, through signal h' the first contact of governor f' and the magnet-coils of governor e_1' to 182, thence through contact-points oe_1'' to 183 to 184, through contact ce_1', and back to battery. Should the train instead of reversing continue on, when it reaches station F it will cause the armature of governor f' to fall, thereby breaking the upper first contact of the governor and closing the lower first contact and leaving the signal h' cut out of circuit when the circuit of battery 180 is completed. When the dotted-line circuit through contact of' is completed the armature of relay e_1'' is raised, completing a circuit from the positive pole of battery 180 to 181, thence through the lower first contact of governor f' and through the magnet-coils of governor e_1' and through the contact of the relay e_1'' to 184, thence through the contact ce_1' to the negative pole of the battery. When the armature of governor f' is raised the signal h' will be restored to "safety," and since the contact-points of the governor are of the continuity-preserving variety there will be no momentary breaking of the circuit of battery 180 when the armature rises.

In a system of automatic block-signals all the apparatus the function of which is to control the positions of the signals should be so arranged that it will have a normal or "safety" position when the track is clear and a "danger" position when a train is on the section of track governed by it; and since trains frequently reverse the direction of their movements and leave the block at the same end at which they entered it, it follows that the signal-controlling apparatus set to "danger" by a train when entering a block should be restored to normal in the same manner no matter which end of the block the train passes out of; and, further, the controlling apparatus must be so arranged that either of two or more trains can operate it in such a manner as to interfere with the independent operation by the other trains of such controlling apparatus as is essential to maintain complete signal-protection. These results I am able to accomplish by the use of the governors and the devices I have shown for operating them, and by the manner in which I locate the track-instruments. For instance, in the situations shown, where two or more track-instruments operate a single governor, these track-instruments are so located and arranged relatively to each other that no conflicting connections can ever result. In order to distinguish between that part of my system the function of which is to control the signals and the signal system *per se*, the section of track between two stations each of which is provided with a governor or two governors and a track-instrument or more than one track-instrument, as at sidings, I term a "governor-block;" and it will be seen that the order of succession in which the governors are operated is in every case uniform, whereas the arrangement of signals controlled by the governors may be widely varied. At double-track crossovers it might perhaps seem that this remark would not apply, but it must be considered when the points of the crossover-track are set for a movement from one main track to the other that the two main tracks become for the time being one track on which the regular order of succession in the operation of the governors is maintained. Likewise when a train leaves the main track and passes onto a siding, the governors are returned to normal just as they would be had the train passed out of the block and into another block of the main track. The only exceptions to the regular order of succession in the operation of the governors are at those situations where a train leaving a block is not required to set succeeding signals to "danger," nor to maintain at "danger" signals previously set to "danger," and hence is not required to cause the armatures of succeeding governors to fall, as at the terminal stations, such as A in Fig. 1, and at sidings and other auxiliary tracks which have no block system of their own. Therefore in my system the road may be said to be divided into signal-blocks and governor-blocks, the two being in general the same, though not always. I have already described the signal-blocks. Every space between two governor-stations constitutes a governor-block, and the connections between the governors and the order of operation of the governors are uniform, whereas that of the signals may be varied to suit the requirements of special situations. Where, as in Fig. 11, two sidings join the main track at substantially the beginning of the same block there is no necessity for block-signals for more than one block, yet the necessity exists for two pairs of governors and the same connections between them as if the space between them were a mile or more.

Fig. 11 shows the arrangement of signals I prefer to employ where two sidings join the main track at nearly the same point and facing in the same direction, and it also serves to make clear the distinction between what I term the "governor-blocks" and the "signal-blocks." The arrangement of the signals is here exactly the same that it is in Fig. 1 at the siding there shown. c''' and c' correspond with the governors so lettered in Fig. 1 and all their connections correspond likewise. The only difference is that the signal-circuits which in Fig. 1 pass through the contact-points of governor c' here also pass through corresponding contact-points of governor z', and those signal-circuits which in Fig. 1 pass only through the contact-points of governor c''' here also pass through corresponding contact-points of governor z'''. Hence a train entering or leaving siding D will have exactly the same effect on the signals that will be had by a train entering or leaving siding D'. The dotted-line circuit connections between track-instruments c and z are, however, just the same that they would be were the distance between them a mile or more, in which case the space between them would necessarily constitute a signal-block and would have signals of its own. The arrangement here presupposes two sidings branching from a single-track road. The same principles apply, however, with equal force to a double-track road and the arrangement of signals required may be modified to correspond where the traffic over the road is ordinarily in but one direction.

Fig. 12 shows the application of a switch-instrument to a quite important situation—viz., that of a siding connected to the main track by a crossover-track. It will be apparent that a train passing from the upper part of the siding to the lower part over the track-instrument 185 should not set the signals on the main track to "danger," and likewise when passing from the lower part of the siding to the upper part should not set the signals of the main track to "safety" in case they should be at "danger;" but when a train passes from the main track over the crossover-track to the upper portion of the siding or when it passes from the siding over the crossover-track to the main track the signals of the main track should be operated exactly as at an ordinary siding. The switch-instrument, therefore, is arranged to complete the full-line circuit and break the dotted-line circuit independently of the track-instrument, when the points of the crossover-track are set to permit the train to move from one part of the siding to the other, so that the governors and signals will not be operated, but puts all of the connections in their normal state when the points of the crossover are set to permit a train to pass from the siding to the main track or vice versa, so that the governors and signals will be operated. Inasmuch as I have in Figs. 6 and 7 fully illustrated the method of using the switch-instrument, I have not thought it necessary in this figure to show the actual connections, but have merely indicated by the description how these connections may be made.

The application of switch-instruments to another very common situation—viz., that of a main track provided with an auxiliary track, which is simply a long double-point siding equipped with a block system independent of the main track—is shown in Fig. 13. F and I are signal-stations on the main track at the ends of the auxiliary track. G and H are signal-stations on the auxiliary track. f, g, h, and i are track-instruments, and 187 and 188 switch-instruments. The governor-blocks between F and G and between H and I correspond exactly with the governor-block between U and V in Figs. 6 and 7. Any desired arrangement of signals may be made, since the governors supply the means for perfectly controlling the signals in the required order. The main track here represented may be either the track of a single-track road or one of the main tracks of a double-track road, in either case the arrangement of the governors and their controlling-instruments being exactly the same, the arrangement of signals, however, depending on the character and amount of traffic. It will be seen that a train passing from the main track to the auxiliary track will set the signals on the auxiliary track to "danger" when it passes over the main-track track-instrument and before it reaches the auxiliary-track track-instrument, and likewise will maintain the main-track signals at "danger" until it has passed entirely onto the auxiliary track, just as described in detail in the description of the circuits of Figs. 6 and 7.

In Figs. 6 and 7, I have shown in detail the manner of controlling track-instrument connections by means of circuit-controlling switch-instruments. There are many other situations than the double-track crossover and the situations shown in Figs. 12 and 13 where it will be found desirable or necessary to use the switch-instruments for controlling track-instrument connections; but Figs. 6, 7, 12, and 13 fully illustrate all the principles involved in the application of the switch-instruments to any situation which may arise.

It is sometimes desirable in automatic block systems that the signal-circuits be so arranged that the rear signals of a block set to "danger" by a train when entering the block shall not only not be set to "safety" again until the train has passed entirely out of the block and into the next succeeding block, but not until the train shall have gotten a considerable distance within the succeeding block. In my system this may be accomplished by having special clearing track-instruments located within the blocks on either side of the regular track-instruments, the clearing-circuit or normally-open contacts of the regular track-instrument being transferred, as it were, to the clearing track-instruments. Fig. 14 shows a plan of this sort. In this figure b is the regular track-instrument, which is provided with the regular normally-closed full-line contact-points, but from the mechanism of which the normally-open dotted-line circuit-contact points are omitted. 189 and 190 are special clearing-circuit relays operating contact-points which correspond to the usual clearing-circuit contact-points of the track-instruments and which are therefore so lettered. b_1 and b_2 are distant track-instruments which control the relays 189 and 190; cb_1 and cb_2 their normally-closed contact-points, and ob_1'' and ob_2'' their normally-open contact-points. 191 and 192 are special open-circuit batteries, the function of which is to energize the magnets of the special relays 189 and 190 when the contact-points of the distant track-instruments are closed. If desired, the circuits of batteries 191 and 192 may be passed through insulated sections of track, as shown, so that the circuits of the batteries will be short-circuited through the wheels of the train if completed before the train has entirely cleared the clearing track-instrument.

The operation is as follows: A train passing over track-instrument b_1 toward track-instrument b does not operate the contact-points of track-instrument b_1. Reaching track-instrument b, it breaks contact cb' and sets the signals at that station to "danger" in the manner already described. When it reaches track-instrument b_2 it closes contacts ob_2', and after the last wheel of the train has passed over the track-instrument closes cb_2, thus completing the circuit of battery 191 through contacts cb_2 and ob_2' and through the coils of the magnet of relay 190, thus closing contact ob' and completing the dotted-line clearing-circuit. The operation for a train moving in the opposite direction is exactly the same.

For a double-track road it will be apparent that the only change required will be to omit one of the distant track-instruments and corresponding relays, the regular track-instrument being provided with the ordinary reverse clearing contact-points shown in Fig. 4. In applying this arrangement of track-instruments to the modification of the system hereinbefore mentioned, where the permissive block system is used and in which the insulated sections of track extend throughout the block, the track-instruments b_1 and b_2, since they put the two rails in electrical connection with each other, must be placed within a short section of track which is insulated from the track on each side, in order that the clearing-circuit may not be short-circuited by the track-instrument and thereby cause the system to be inoperative. The two rail-sections on each side of the track-instrument will in this case be connected by wires. If desired, there may also be a short rail-section insulated in the same way from the section extending between the regular and special clearing track-instruments (the resulting subsections being again connected by wires as in the case of the track-instrument just mentioned) for the purpose of short-circuiting the circuits of the special clearing-batteries in case these circuits are completed before the last wheels of the train have passed over the clearing track-instrument. It will usually be desirable to provide these insulated sections, since they reduce the required distance between the regular and special clearing track-instruments to a degree equivalent to the length of the longest train, and hence reduce the length of the circuit of the special clearing circuit-battery.

If desirable, the space between two passing points on the road, such as stations F and I, Figs. 2 and 3, may be divided into two or more blocks, and the front signals may be connected so that the space will constitute two or more front blocks, or one or more signal divisions, if desired.

In my system, where the distance from the caution or distant signal to the home-signal is sufficiently great, its controlling-magnet may be placed in the circuit of a separate local battery instead of being in a branch circuit of the main local battery, as shown, and several distant signals may be placed in the same circuit, which, in some cases, is very desirable. The distant signals for one block may be placed side by side with the home-signals of the preceding block, if desired, this arrangement in regard to locating them being especially desirable where the blocks are very short, inasmuch as both may then be operated by branches from the same battery.

It will be seen that any of the signal or front relay-circuits may be broken by a hand circuit-breaker in the circuit, if desired, without affecting the governor-circuits. Hence the signals may be operated by hand by simply placing a suitable circuit-breaker in any of the signal-circuits desired to be operated in this way. It will be also apparent that the closing of the signal-circuits through such hand-operated circuit-breaker will merely have the effect of putting the signal-circuits into the condition shown in the drawings, and therefore can in no way affect the automatic setting to "danger" of the signals. Where the governors and signal-magnets are in series, as shown at station E, Fig. 2, and station L, Fig. 4, the hand circuit-breaker must be provided with continuity-preserving contact-points, the action of which in relation to the signal and governor circuits is similar to that of the front relays e'' and e'''' at station E, Fig. 2.

Where the duplex arrangement for operating the signals is used, as shown in Fig. 9, it is evident that the signals may be operated by hand by simply placing in their circuits hand-instruments making connections like ordinary telegraphic transmitters.

I have described and illustrated in this application the method in which my signaling system may be applied to the general cases of single-track and double-track roads, and to all the fundamental situations likely to be met—as, for instance, terminals, sidings, both double-point and single-point, and double-track crossovers—but it is evident that there are an endless number of other situations requiring special signal arrangements differing more or less from each other and to which my system may be applied, but all of which it would be impossible to show. For instance, sidings frequently have other sidings branching from them, and again, on double-track roads, sidings have crossovers at their ends so as to make the sidings accessible from both tracks. Other situations of a still more complicated character might be mentioned. These situations, however, are all modifications, aggregations, extensions, or combinations of the fundamental situations shown in this application, and my system of signals may be adapted to any of these situations, and make a continuous block system between any number of tracks branching from each other by following out the principles which have governed the extension of this system from the general case of the line uncomplicated in any way to the fundamental situations shown, which principles are as follows:

First. Any of the circuits may be broken or closed when necessary by more than one track-instrument.

Second. Any of said circuits may be closed, broken, or controlled by insulated closed or open contact-points of switch-instruments operated by the switch-throwing mechanism, any number of contact-points may be operated by the switch-instrument, and any number of such contact-points may be continuity-preserving contact-points.

Third. Any required number of contact-points, normally open or normally closed, may be included in the mechanism of any track-instrument and operated thereby.

Fourth. Governors and relays may be provided with any number and arrangement of contact-points, and two or more relays or governors may be connected either in multiple or series.

Fifth. As many separate batteries or other sources of electrical energy may be provided as may be required.

Sixth. The insulated rail-sections and corresponding connections for short-circuiting clearing-circuits when a train is standing over the track-instrument may be modified in any required manner.

Seventh. Any required number of governors may be controlled by one track-instrument, any number of track-instruments may control one governor, and any number of governors may control one or a series of signals, provided that the connections be such as not to interfere with each other.

Eighth. Any normally-open circuit may be normally broken in two or more than two places, so that to close it requires that all the breaks shall be closed simultaneously. Any normally-closed circuit may be closed and completed separately by more than one pair of contact-points, so that all of these points must be separated simultaneously in order to break the circuit, and any of the breaks and closures may be made by the same or different instruments belonging to the system.

Ninth. Relays controlling local batteries to operate any of the magnets of the system may be provided where on account of the high resistance of the line or for any other reason this is necessary or desirable.

Tenth. Any number of governor-blocks may be included within one signal-block, as shown in Fig. 11, and the governors may be made to control any one or more than one signal.

Eleventh. Any section of road may be divided into any desired number of blocks and signal-divisions.

In describing the operation of my system, I have only described the principal train-movements, such as are usually made, since the number of possible train-movements are endless; but it will be seen that no matter how intricate these movements may be the signal-controlling apparatus of my system, and hence the signals, must always respond, so that the signals are always set to "danger" and "safety" in the order required.

It will be observed that in my system all the circuits the function of which is to set signals to "danger" are circuits which are normally closed, and which, when closed, hold the signals at "safety," the breaking of a circuit in any way resulting in the setting to "danger" of the signals which it controls, so that any accident to the circuits by which they are rendered inoperative results in the setting to "danger" of the signals. Also, it will be observed that all of the circuits the function of which is to restore signals to "safety" are normally-open circuits, and any accident by which one of them is rendered inoperative makes it impossible to restore to "safety" the signals which the circuit controls. Therefore, no accident can result from the breaking of a clearing-circuit.

In order to avoid derangement of circuits and false operation of signals due to crossing of signal-wires I have provided each circuit with a return-wire, and have in every case avoided grounding a circuit, so that the crossing of two wires cannot result in the passage of current from one wire to the other.

I do not limit myself to the use of batteries to supply current to the circuits. In many localities it may be more convenient and economical to use other sources of electricity; and the batteries shown in the drawings of this application are to be regarded as merely typical representations of electrical generating devices in general.

In some situations it will be desirable to have the dotted line, or clearing-circuits, of my system operated by relays similar to relays 189 and 190, Fig. 14, which are operated by the regular track-instrument that is placed at the point of division between two blocks, and the relays may be in branch-circuits from the same battery. Also, relays corresponding to 189 and 190 may be provided with as many contact-points as required. This arrangement will be especially desirable for those locations where good insulation of the rail-sections cannot be obtained, as in such situations the leakage in wet weather might be sufficient to seriously interfere with the working of the clearing-circuits where the clearing-circuits were made to pass directly through the insulated sections. These auxiliary clearing-circuits will also prove of especial value in the application of my system to very complicated situations.

Having thus completely described my improved system of railway-signaling and its operation, what I claim, and desire to secure by Letters Patent, is—

1. In an electrical railway signaling system, the combination, with two or more blocks or sections of track forming a signal division, track-instruments at the ends of said blocks, and a signal at each end of each block controlling the entrance of trains to said block at the end at which said signal is located, of a circuit for each signal controlled by the corresponding track-instrument and adapted to set said signal to danger when a train passes over said track-instrument and into the block to which said signal belongs, two front signal circuits for the division, each controlled by a

track-instrument at one end of the division and controlling the signals of the division which control trains within the division moving toward that track-instrument, and adapted to set said signals to danger when a train passes over said track-instrument and into said division, clearing circuits for the signals of each block operated by the track-instruments at the ends of said block and adapted to clear said signals when a train has passed out of said block, and means for clearing all of the signals of the division yet uncleared when the train passes out of the division, substantially as described.

2. In an electrical railway signaling system, the combination, with a block or section of track, of a track instrument, governor, and a local closed circuit battery at one end of said block, and a governor closed circuit passing through the governor magnet and normally closed contact points of the governor and track instrument, substantially as described.

3. In an electrical railway signaling system, the combination, with a block or section of track, a track instrument at each end of said block, a governor and a local closed circuit battery at one end of said block, and a governor closed circuit passing through the governor magnet and normally closed contact points of the governor and local track instrument, of a governor open circuit battery at the distant end of the block from the governor, and a clearing circuit from said battery passing through the governor magnet and normally open contact points of the governor and distant track instrument, substantially as described.

4. In an electrical railway signaling system, the combination, with a block or section of track, a track instrument at each end of said block, a governor and a local closed circuit battery at one end of said block, and a governor closed circuit passing through the governor magnet and normally closed contact points of the governor and track instrument, of a governor open circuit battery at the distant end of the block from the governor, a clearing circuit from said battery passing through the governor magnet and normally open contact points of the governor and distant track instrument, and a signal circuit passing through the contact points of said governor, substantially as described.

5. In an electrical railway signaling system, the combination, with a block, as B. C, governors, as b' and c''', one at each end of the block, track instruments as b and c, one at each end of the block, the full-line batteries at B and C and the full-line branches of these passing through the track instrument contact points, the governor magnet, and the governor contact points, as on the right at station B and on the left at station C, of the dotted-line open circuit batteries at B and C and the clearing circuits branching from these and passing through the track instrument contact points, the governor magnets and governor contact points, and the dotted line circuit extending throughout the block and connecting electrically the governors at each end of the block together; the track instrument at each end of the block being adapted to break the corresponding full-line circuit upon the entrance of a train at either end of the block, whereby the armature of the governor at the end of the block at which the train enters drops to the danger position; and adapted to complete one of the dotted line circuits when the train passes out of the block at either end, whereby the armature of the governor, or of both governors if both be down, is restored to the normal position, substantially as described.

6. In an electrical railway signaling system, the combination, with a block as B C, a track instrument, governors, and a closed circuit battery at each signal station, and branch circuits from said battery passing through the governor magnets and through the contact points of the governors and track instrument, of signals at each signal station, local signal circuits controlled by said governors for controlling said signals, and clearing circuits for restoring to safety the governors, and the signals in rear of a train, substantially as described.

7. In an electrical railway signaling system, the combination, with a block or section of track, a home signal at each end of the block, and means for setting both of said home signals to danger when a train enters said block, of a special front signal at each end of the block, a circuit therefor, and a track-instrument controlling said circuit and situated at the distant end of said block from said special front signal, and adapted to set said special front signal to danger when a train passes over said track-instrument into said block, substantially as described.

8. In an electrical railway signaling system, the combination, with a section of road as A C, divided into blocks, as A B and B C, and track instruments and governors controlled thereby at the entrance of every block, of front relays for each direction of movement at each signal station, a front signal battery, as 16 for each direction, and a circuit therefor passing through contact points of the governors for one direction of movement of trains, as governors a' and b', and through the magnets of the front relays controlling the signals governing the other direction of movement of trains, as b'''' and c'''', signals at each signal station and local signal circuits therefor passing through contact points of the local governors and front relays, substantially as described.

9. In an electrical railway signaling system, the combination, with a block or section of track, as B C, provided with a side or auxiliary track, and signals for said block, of a main track instrument c provided with contact points cc'' and a circuit passing through those contact points for setting to danger sig-

nals within the block B C when said contact points are operated, and other contact points oc' and a circuit passing through said contact points for clearing signals in the block B C when said contact points oc' are operated, of a siding track instrument d provided with contact points cd'' operated by a train in passing from the siding over said siding track instrument and connections for said contact points cd'' whereby the same signals are set to danger in the block B C when said contact points are operated as are set when contact points cc'' are operated, and likewise provided with other contact points od' operated when a train passes from the main track over said track instrument d on to the siding and connections for said contact points od' whereby the same signals are cleared by the operation of said contact points as are cleared by the operation of contact points oc' of track instrument c, substantially as described.

10. In an electrical railway signaling system, the combination, with a section of track F I provided with a double point siding, a governor f', track instrument f, and a governor circuit passing through the magnet of said governor and through contact points of the said track instrument and governor, of insulated sections of the main track rails extending throughout the distance between the points of the siding, a track instrument i, a clearing circuit battery 62, and a circuit therefor passing through contact points of the track instrument i, through the magnet of governor f' and through the above mentioned insulated sections of track, substantially as described.

11. In an electrical railway signaling system, the combination, with a section of track F I, a governor f', a track instrument f, and a governor circuit passing through the magnet of said governor and through the contact points of said track instrument and governor, of insulated sections of track extending throughout the block, a track instrument i, a clearing circuit battery 62, and a circuit therefor passing through contact points of the track instrument i, through the magnet of governor f', and through the above mentioned insulated sections of track, substantially as described.

12. In an electrical railway signaling system for crossovers, the combination, with track instruments u and v at the ends of the crossover track and signal operating circuits controlled by the contact points of said track instruments, of the switch instruments u_1 and v_1 operated by the movement of the switch throwing mechanism of the crossover track, and circuits passing through contact points of said track instruments and switch instruments, whereby when a train passes from one main track over the crossover track to the other main track front and rear signals on the track which the train enters are set to danger when the train passes over the track instrument at the entrance of the crossover track and the front and rear signals on the track which the train leaves are returned to safety when said train passes over the track instrument at the end of the crossover track, substantially as described.

13. In an electrical railway signaling system, the combination, with a block or section of track as A B, Fig. 9, of two batteries of unequal strength, as 164 and 165, and the dashed line circuits branching from them, governor contact points as the first and second contact points of governors a' and b''', adapted to cut out one of the batteries and one of the coils of the front relay and the rheostat when the armature of the governor is in the danger position, and to connect the line and the other relay coil with the return conductor of the circuit, of two differentially wound polar relays, one at each end of the block, as a'' and b''', adapted to control the front signals and front relays of the system and to cause the signals controlled to go to danger in case of great line leakage, of two rheostats as 167 and 168 adapted to balance the resistance of the line, and of two relays as a^4 and a^5 placed in the line circuit, one at each end of the block, and adapted to set the signals at each end of the block to danger upon the breaking, or a great increase in the resistance, of the line wire, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

THOMAS BULLITT DIXON.

Witnesses:
JAS. CHRISTOPHER,
HARRY LYNE.