ELECTRIC INTERLOCKING

ROCHESTER
GRS
N. Y.

GENERAL RAILWAY SIGNAL COMPANY

ROCHESTER, N. Y.

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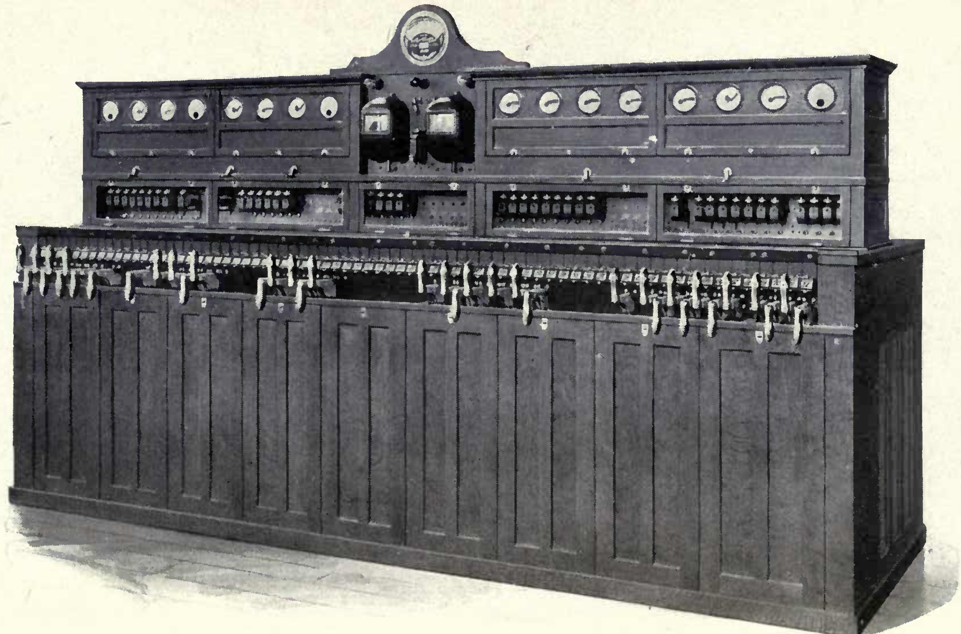

G. R. S. ELECTRIC INTERLOCKING MACHINE
(See Figs. 29 and 32.)

ELECTRIC INTERLOCKING HANDBOOK

BY THE
ENGINEERING STAFF OF THE
GENERAL RAILWAY SIGNAL COMPANY
WITH AN INTRODUCTION BY
WILMER W. SALMON

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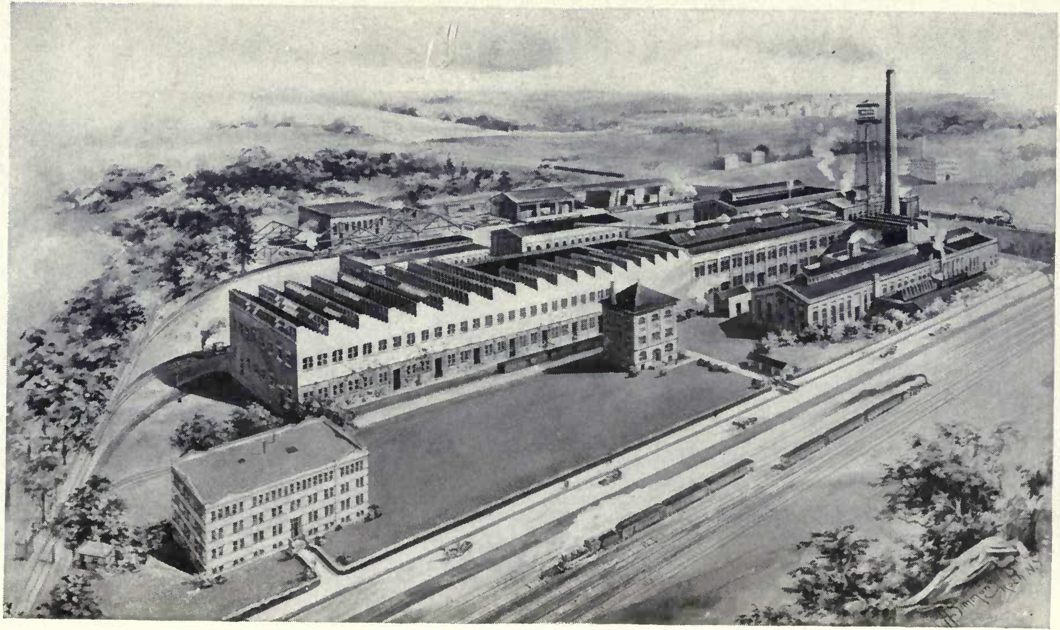

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INTRODUCTION

INTERLOCKING is of English origin, numerous patents having been granted in England for manually operated interlocking devices from 1856 to 1867, at which later date was first disclosed by Saxby a satisfactory means for obtaining what is now known as "preliminary latch locking." The rapidity with which this valuable system was adopted in England is indicated by the fact that six years later, in 1873, 13,000 mechanical interlocking levers were employed on the London & Northwestern Railway alone, at which time not a single lever was in use in the United States, the first experimental installation having been made in this country by Messrs. Toucey and Buchanan at Spuyten Duyvil Junction, New York City, in 1874, and the first important installations on a commercial basis having been made by the Manhattan Elevated Lines of New York City with machines of the Saxby-Farmer type, built by the Jackson Manufacturing Co. of Harrisburg, Pa., in 1877-78.

Very soon after American railways had gained a little experience with mechanical interlocking plants, it was felt that there were many situations where great economies could be effected and more satisfactory operation obtained if switches and signals could be successfully worked by power instead of manually. For precisely the same reason — viz: saving of labor — that English railways were first led to concentrate in a single frame the theretofore widely separated levers for the operation of switches and signals — thus leading up to the idea of interlocking — so the much higher cost of labor in the United States than in England caused the American railways to demand an interlocking that would afford means for operating switches and signals over greater distances and with fewer operators than were required under the English method. The first concrete response of the American inventor to this demand was the Hydro-Pneumatic Interlocking installed in 1884 near Bound Brook, N. J., at the crossing of the P. & R. and L. V. R. R. From 1884 to 1891, eighteen Hydro-Pneumatic plants, having 482 levers, were installed on six railways, but this system having developed many serious defects, its inventors devised and in 1891 installed the first electro-pneumatic plant at the Chicago & Northern Pacific Drawbridge, Chicago. In the following ten years, there were ordered — up to June 1, 1900 — fifty-four electro-pneumatic plants, having 1,864 levers, for use on thirteen railways. It was felt at this time that while power interlocking had been proven to be usable with advantage in a few important situations, it fell far short of accomplishing all that was desired and required of it by the railways, and it was even then believed by some engineers that owing to certain defects and limitations inherent in the electro-pneumatic principle itself, some safer, more reliable and economical system would have to be developed before power interlocking could, with wisdom, be more generally employed.

Just at this time (May, 1900) a company was formed to develop and exploit the electric interlocking patents now owned by the General Railway Signal Company and embodying the now well-known "dynamic indication" principle. In 1901 this Company put in service its first electric interlocking plant employing the dynamic indication, at Eau Claire, Wis., on the C. St. P. M. & O. R'y. As might have been expected, in view of the newness of the idea, and of the Company exploiting it in opposition to an old-established and rich competitor, its progress was slow; but, the idea being right, its progress has been steady and sure, with the result that in the eleven years since its first plant went into service, it has furnished for use on eighty-three railways in thirty-five States and Provinces of the United States and Canada, 440 of these plants, having 21,370 levers. In the sixteen years from the installation of the first commercial pneumatic machine, during which time no competitive power interlocking machine was on the market, the average annual sales were four and five-tenths machines and 147 levers. In the eleven years following the installation of the first commercial dynamic indicating electric interlocking machine, and in competition with all other types of power interlocking, our average annual sales have been forty machines and 1,943 levers. With but few exceptions, American railways requiring power interlocking now exclusively specify the "all electric," and while the success achieved with our "dynamic indication" system has led a number of companies to devise and offer electric systems, it is believed conservative to state that much more than 90 per cent. of all the electric interlocking in use in the United States is of our manufacture. A more exact statement of percentage cannot be given for the reason that, so far as we have been able to ascertain, other makers of power interlocking plants have not in recent years seen fit to give publicity to the number of power plants and power levers installed by them, though prior to our advent in this field such statements were frequently published. It can, however, be positively stated that more of our electric plants and more electric levers have been installed on American railways in this past ten years than of all other types of power interlocking in the past twenty-eight years.

An evolution so rapid, extensive and radical as this cannot fail to suggest an inquiry into its causes and what bearing they may or should have upon the interlocking practice of the future.

During the annual meeting of the Railway Signal Association at Buffalo in October, 1901, one of the principal questions discussed was, "At what leverage is it economical to install power interlocking rather than mechanical." The consensus of opinion then seemed to be that power plants might be economically used where and only where, on account of the size of the machine or density of traffic or for any other reason, more levermen would be required to operate a mechanical than a power machine. At that time the writer hazarded the opinion that in the course of time mere size of plant and density of traffic would cease to be generally regarded as the sole or even as very vital factors in arriving at a choice between power and mechanical interlockings; that signalmen who were at that time obliged to compare the advantages of mechanical interlocking with those of the only power interlocking with which they then had experience, the electro-pneumatic, might reasonably be expected to change their views very materially when they came to be familiar with the advantages of "all electric" interlocking. How far this forecast, which was then regarded by many able, experienced signalmen as visionary, was warranted may be judged by an examination of tables in this handbook showing hundreds of small and medium sized electric interlocking plants installed by us in the decade that has elapsed since then, thus affording evidence that not only is electric interlocking rapidly displacing all other types of power interlocking but that it is being largely and increasingly used where formerly nothing but mechanical interlocking would have been considered. The writer believes now as he believed ten years ago that certain of the important reasons for this change are found in the following facts:

Entirely aside from considerations of economical operation that obviously demand the usage of power interlocking at all points where more than one leverman would be required for the operation of a mechanical plant, or where train movements are so numerous as to make the operation of such a plant too great a physical strain upon the operator, there are other and equally important features to be considered with respect to every proposed new interlocking, chief of which is the fact that no purely mechanical interlocking ever devised is anywhere near so safe as is the dynamic indicating electric interlocking. In spite of the now general recognition of this fact, it must be remembered that it was only as the electric interlocking came to be commonly used and its safety features to be compared with those of straight mechanical interlocking that the defects and dangers of the latter became emphasized by the contrast. Thus, beginning about ten years ago, the realization of this fact by skilled signalmen led them, at first slowly but as time has gone on more and more rapidly, to one of two practices, viz: the use, on the one hand, of electric interlocking, pure and simple, or, on the other, adding to mechanical interlocking all sorts of electrical apparatus and circuits. Where the latter expedient is adopted, the resultant composite plant requires a maintainer combining the experience of a mechanic and of an electrician, and such men are not numerous. Fifteen years ago the number of young men who had even a rudimentary knowledge of electrics was small; but—owing to the enormously increased employment of electricity in telegraphy, telephony, lighting, manufacturing and transportation; to the institution of simple courses in electricity in trade, industrial and correspondence schools; and to the fact that it is easier and takes much less time to acquire a usable working knowledge of electrics than to become a fairly skilled mechanic — most railways now find it possible to procure, at the prevailing wage rate, men capable of maintaining electrical rather than mechanical installations—particularly since the automobile and kindred industries have created such an unprecedented demand, at high wages, for mechanics.

Another fact having an important bearing on this phase of our subject is this: American block signal practice, like its interlocking practice, was originally copied from the English, who employed the manual system. In block signaling, as was the case in interlocking, the American demand for labor saving devices early led to the invention of power operated automatic block signals, the first of which to be employed on a considerable scale were of the pneumatic type. Now, in automatic block signaling. as in interlocking, the electric is almost entirely supplanting the electro-pneumatic, and few, if any, American railways are now considering anything but electric signals for new block work. Such signals are now used on upwards of 35,000 miles of American railway, and large additions are being made thereto annually. It will hardly be denied by any engineer skilled in signaling that every interlocking plant located in automatic, electric, block signaled territory should be electric, since, if for no other reasons, it can be more simply installed, more economically maintained and more reliably operated than a mechanical or any other type of interlocking which would require the mixing in with the necessary electric block devices of other types of apparatus requiring maintainers and repairmen having needed training in two or more trades rather than in one. This is a consideration, which, quite apart from that of maximum safety, has led many railways to the installation of a great deal of electric interlocking in automatic block signaled districts and which is influencing them and others to take like action where automatic block signaling, though not in immediate prospect, may be put in within a few years.

Thus it has come to pass that of the railway men who still feel that the mechanical interlocking when provided with various electrical adjuncts may be made to be almost if not quite as safe as the "all electric plant," more and more are coming to realize that simplicity, economy and reliability demand the usage of the electric interlocking in preference to any others, particularly as a mechanical plant, even when equipped with the most elaborate system of electrical adjuncts, has not changed its nature but still remains a mechanical plant, subject to most of the operating difficulties inseparable from such a plant.

Another situation that has largely influenced the adoption of electric interlocking is the following: Up to the time of the introduction of electric interlocking, it was the rule, rather than the exception, for American railways to operate from interlocking machines at ordinary crossings and junctions such switches as were within 700 to 800 feet of it, but not to operate or adequately signal more distant switches. Where any connection existed between such distant switches and the interlocking it was usually no more than that established by having an electric circuit controller on such a switch by means of which an electro-magnetically slotted distant signal alone was prevented from giving its proceed indication when the switch was open between it and the home signal. It was claimed by the railways, not without reason, that it was too difficult and costly, and in some instances impossible, to satisfactorily operate such switches from a single machine and that it would be the height of folly for them to install one or more additional machines merely for the sake of operating these switches, the interlocking of which would not have been at all considered at the moment except for their proximity to junctions or crossings they were obliged to interlock. Gradually, however, for one or another reason, American practice is coming more and more approximate to that of England, where every main line switch on a passenger carrying road has to be properly signaled and interlocked, and coincident with and probably largely responsible for this changed attitude of the American railways is the now almost universal recognition of the fact that electric interlocking alone affords the means for successfully accomplishing this in the United States without excessive cost for both installation and operation. Many of our electric plants have for years satisfactorily operated switches, together with their allied signals, located from one to six thousand feet from the interlocking machine, sometimes with tunnels or other obstructions to view, intervening between the interlocking station and the switches. In fact, as temperature changes, no matter how great or how sudden, do not in any degree affect the operation of our electric plants, they being absolutely free from such disorders as, in a mechanical plant, occur because of contraction or expansion of parts connecting the interlocking levers with the switches and signals, and as the "dynamic indication" features and the "illuminated track diagrams" make it wholly unnecessary for the operator to see tracks, trains, switches, or signals — there is absolutely no limit to the distance at which such switches and signals can be safely, reliably and expeditiously worked by means of our electric interlocking. As an illustration, it may be of interest to note here that by far the largest interlocking plant in the world, one of our dynamic indicating type, at the Grand Central Terminal of the N. Y. C. & H. R. R. R., New York City, is operated most successfully under conditions where it is impossible to have any view from the interlocking station of trains, tracks, switches, or signals.

It would be possible, as is recognized by all who have closely observed and carefully studied the trend of American signal practice for a score or more of years, to cite almost numberless additional conditions each of which has had some part, big or little, in determining why it is that electric interlocking has been and is being increasingly installed in units varying all the way from four to four hundred levers; why it is used with equally satisfactory results at small junctions, yards and crossings where traffic is light; at hundreds of points of medium traffic where machines of from sixteen to forty-eight levers are required and at the busiest and largest terminals; but such a citation would be long, and after all, the whole matter can be briefly summed up by saying that the reasons why more of our dynamic indicating electric interlocking machines have been installed in the last ten years than of all other types of power interlocking in the past twenty-eight years, and why they are being so largely employed where formerly only mechanical machines would have been considered are — that experience has fully demonstrated that wherever and under whatever conditions of traffic or climate our dynamic indicating electric system has been tried it has been found superior to every other type of interlocking, in safety, reliability, economy and rapidity of operation and in its adaptability to every present and prospective need of the user. For these reasons, the writer hazards the prediction that within the next ten years many important American railways will closely approximate to a condition where every block signal and every interlocking machine, large and small, over long stretches of their main line will be controlled, operated and lighted by power supplied from central energy stations, and where, in consequence, mechanical or any other than electric interlocking will be almost as much a thing of the past as is the "horse car" on the street railways of to-day. To such readers as may be inclined to regard this forecast as wild or visionary, the writer suggests the perusal of the preface prepared by him for the 1902 Electric Interlocking Catalogue, and that this may be readily done, that preface is reprinted herein (see page 405). After noting the forecasts made in 1902 and finding that every claim therein advanced for the then newly introduced electric interlocking system has been fully met and that its general adoption has more than realized the most sanguine expectations then entertained for it — the reader may be less inclined to be over skeptical as to the prediction made for the coming decade.

To meet the requirements of the many present and prospective users of our dynamic indication electric interlocking, we have prepared this Handbook, wherein it is sought to furnish data that will be useful to all those seeking a true understanding of the dynamic indication principle, and to those who are required to prepare bills of material for, or to install, operate or maintain our electric interlocking.

W. W. S.

SECTION I

G. R. S. ELECTRIC INTERLOCKING SYSTEM

SETTING FORTH THE PRINCIPLES INVOLVED AND GIVING A BRIEF DESCRIPTION OF THE APPLIANCES USED

G. R. S. ELECTRIC INTERLOCKING SYSTEM

Requisites of a Properly Designed Interlocking System

INTERLOCKED switch and signal appliances were first devised and used at junctions and terminal points for the purpose of reducing the number of men employed to go from switch to switch, throw them by hand and then give a hand signal for the train to proceed over the route thus lined up. It was soon found that operating the switches and signals from a central point under the control of the levers in an interlocking machine greatly expedited the handling of traffic. By far the greatest accomplishment of interlocking, however, was the addition of an enormous factor of safety at such points to train operation.

Inherent in the system of mechanical interlocking which first was employed to control the switch and signal functions were certain recognized shortcomings as regards safety and facility of operation.

Systems of power interlocking in the field prior to the introduction of the electric dynamic indication system, now owned and manufactured by the General Railway Signal Company, although giving increased facility of operation, did not and do not provide the greatest safety obtainable with this increased facility.

The features of vital importance in considering the merits of any system of power interlocking are those which are designed to give the greatest measure of safety together with facility of operation. The two features most important to safety are:

First — The means provided to check the correspondence of movement between lever and the switch, signal, or other function controlled by it.

Second — The means for preventing unauthorized movement of switches, signals, or other controlled functions.

The reliability of the means by which the above protection is secured determines more than anything else the safety of a given system of interlocking. In fact, this is so vital that an interlocking plant without a thoroughly dependable system for insuring correspondence between its levers and the operated functions, and for preventing the unauthorized movements of such functions, is absolutely unsafe.

The G. R. S. electric interlocking system fully meets the first important requirement of checking the correspondence of movement between lever and operated function by means of the *dynamic indication*, energy for which is furnished by a momentary dynamic current generated by the motor of the operated function itself when and only when the actual operation of such function shall have been properly completed. Contrast this with systems employing A. C. or battery indication, in which the indication is secured from energy existent at the function prior to and during the movement of that function and dependent only on the closing of a single break in the indication circuit.

The use of the dynamic current, generated by the momentum of the motor of the *operated unit at one end of the circuit* and so giving the desired indication at the *lever at the other end of the circuit*, prevents the receipt of a false indication due to a

Fig. 1. Lake Street Interlocking Plant. Chicago Terminal, C. & N. W. R'y

cross between the wires of the circuit, and is, therefore, correct in principle.

The unauthorized movement of switches or derails, or the improper clearing of the signals is prevented by a simple and effective method of cross protection, the basis for which is inherent in an electric interlocking system using dynamic indication. It is a notable feature that the second requirement is met by a means in which all the contacts required for this protection form a part of the operating circuit, thus checking their integrity at each operation.

In order to fully consider the advantages of the G. R. S.

system of electric interlocking, its elements are described in more detail as outlined below.

Elements of G. R. S. Electric Interlocking System

A complete installation of the General Railway Signal Company's electric interlocking system comprises the following elements:

First — A source of power consisting of a storage battery with its charging unit.

Fig. 2. Collinwood Interlocking Plant. L. S. & M. S. R'y

Second — Power control apparatus introduced between the source of power and the interlocking machine.

Third — An interlocking machine with levers for the control of the switch and signal mechanisms.

Fourth — Switch mechanisms, their operating and indicating circuits.

Fifth — Signal mechanisms, their operating and indicating circuits.

Sixth — Means for the prevention of unauthorized movement of any function.

In connection with such a system may be installed such accessories in the way of track circuits, detector locking, route locking, indicators, annunciators, etc., as may be desired at each individual installation.

Source of Power

The source of power, from which the G. R. S. system of electric interlocking is operated, consists of a storage battery having an approximate working potential of 110 volts, this battery being charged by a power generating unit, which frequently is a generator driven by a small gasoline engine.

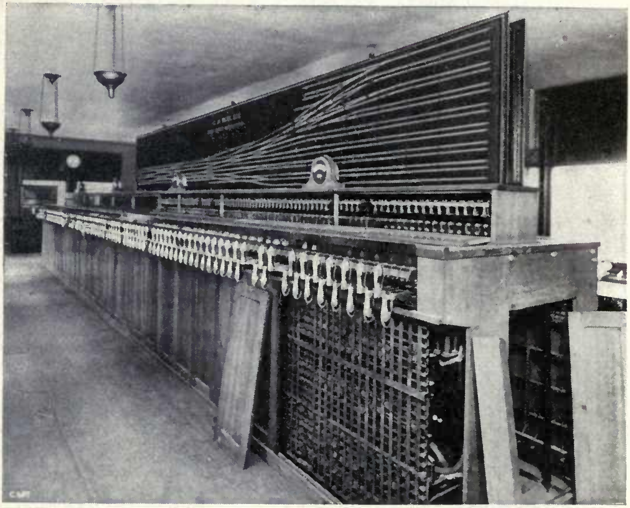


Fig. 3. Model 2 Unit Lever Type Interlocking Machine. Lake Street Interlocking Plant, Chicago Terminal, C. & N. W. R'y

Power Control Apparatus

Power is delivered to the interlocking machine under the control of protective apparatus, mounted on suitable switchboards.

Interlocking Machine

The operation of each switch and signal function is controlled by levers, which with their respective locking tappets, indication magnets and circuit controllers, are mounted in a common frame, the whole being known as an interlocking machine.

Starting with the lever in either of its extreme positions, the stroke of the lever is divided into two movements. The first movement locks all levers conflicting with its new position and operates the function. The second and final movement of the stroke releases such levers, hitherto locked, as do not conflict with its new position. Except in the reverse position of a signal lever, this final movement can be made after, and only after, the dynamic indication has been received certifying that the operated function has assumed a position corresponding with that of its lever.

Switch Mechanism — Its Operating and Indicating Circuits

Each switch and derail is thrown and locked by a switch and lock movement driven by a series wound direct current

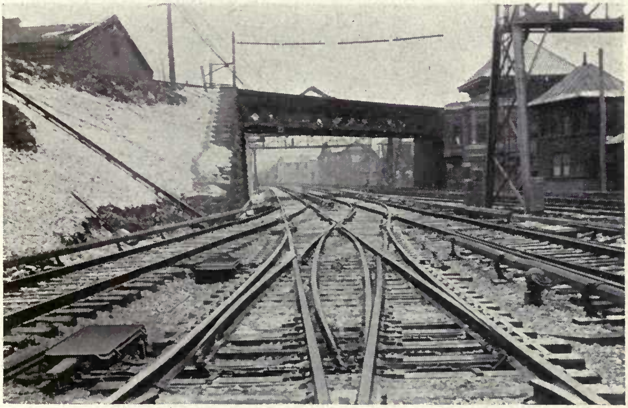


Fig. 4. Model 4 Switch Machines High Bridge, Tower "A," Electric Division, N. Y. C. & H. R. R. R.

motor. Two wires are used for its control, one for the normal and the other for the reverse operation. These same wires are used for indicating purposes, the normal control wire being used for the reverse indication and the reverse control for the normal indication. The circuit is connected to main common at the switch location.

The circuits for a switch are shown in simplified form in Fig. 5, the operating and indicating currents in the different diagrams being shown by the red lines.

When the switch (normal position) is to be operated, the first movement of the stroke of the controlling lever carries it as far as the reverse indication position and permits current to flow as shown in Fig. 5B, which causes the mechanism to move the switch points to the reverse position and lock them in that position. When this movement has been completed the

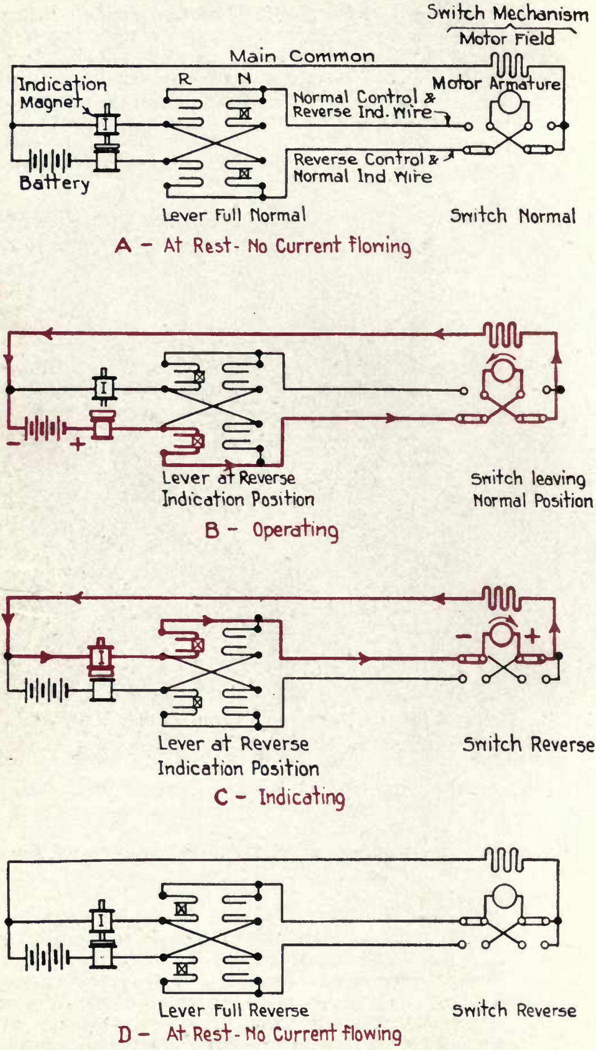


FIG. 5. SIMPLIFIED CIRCUITS FOR MODEL 2 OR MODEL 4 SWITCH MACHINE

circuit through the switch motor is automatically changed, disconnecting the motor from battery and connecting it in a closed circuit including the indication magnet (Fig. 5C); at the same time the armature terminals are reversed for indication purposes, this leaving the motor connections in proper position for the next operation. The motor (now a generator) with the momentum acquired during the operation of the switch movement, generates a momentary current which energizes

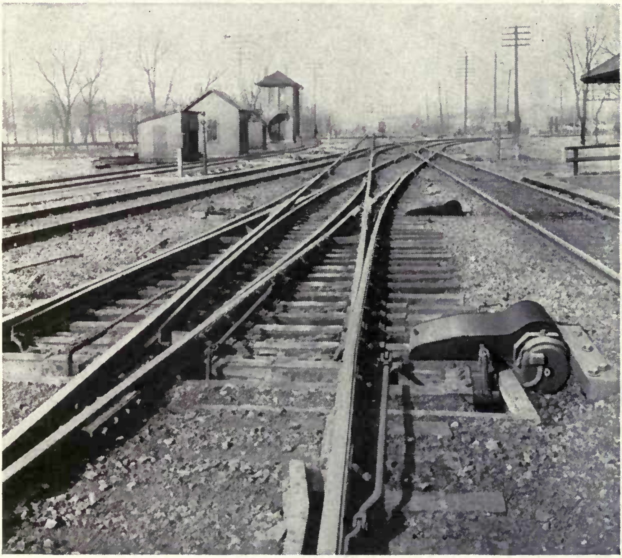


FIG. 6. MODEL 2 SWITCH MACHINES. MAYFAIR INTERLOCKING PLANT, C. & N. W. R'Y

the indication magnet, thus permitting the final movement of the lever to be completed (Fig. 5D).

The operation of the lever and function from the reverse to the normal position is accomplished in the same manner.

A useful feature, not usually obtainable in other power systems, is that the movement of the switch points may be reversed at any portion of their travel at will by the operator, and the lever movement completed upon the switch points assuming a position corresponding with that of the lever, irrespective of the direction of the first movement made by the lever.

The complete switch operation and final movement of the

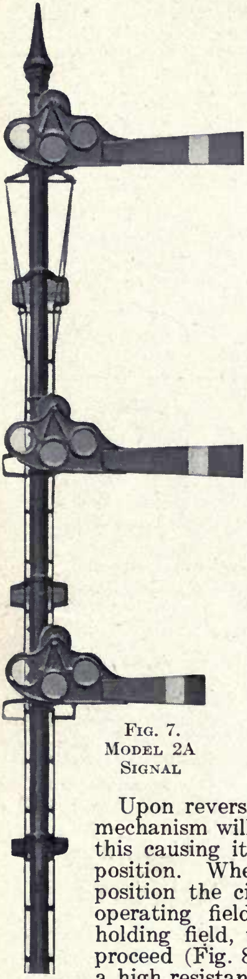


Fig. 7.
Model 2A
Signal

lever may be accomplished in from two to two and one-half seconds, the indication being practically instantaneous with the completion of the switch operation.

Signal Mechanism — Its Operating and Indicating Circuits

The description of signal mechanisms will be confined to the non-automatic, two position signal, as this will show the principles involved in all types of motor driven signals now used in the system.

This signal is operated by a mechanism in which the motor is directly connected to the semaphore shaft through low reduction gearing. The signal is held at proceed during such time as its controlling lever is in the reverse position solely by a dense magnetic flux thrown across the air gap between the motor armature and the field pole pieces (holding field pole surfaces are serrated) by cutting the windings on the holding field poles in series with the operating field windings.

Each signal requires for its operation and indication one wire and a connection to the common return wire.

A simplified circuit for this type of signal is shown in Fig. 8, the path taken by the operating, holding, and indicating current in the different diagrams being shown by the red lines.

Upon reversal of the controlling lever, the signal mechanism will receive current as shown in Fig. 8B, this causing it to move the blade to the proceed position. When the signal blade has assumed this position the circuit breaker cuts in series with the operating field and armature, the high-resistance holding field, thereby retaining the signal arm at proceed (Fig. 8C). The holding field windings have a high resistance, which reduces the current to that employed for holding the signal at proceed.

When the signal lever is placed in the normal indicating position, energy is cut off from the motor and the blade returns to the stop position by gravity, causing the signal mechanism and motor armature to revolve backward to their original

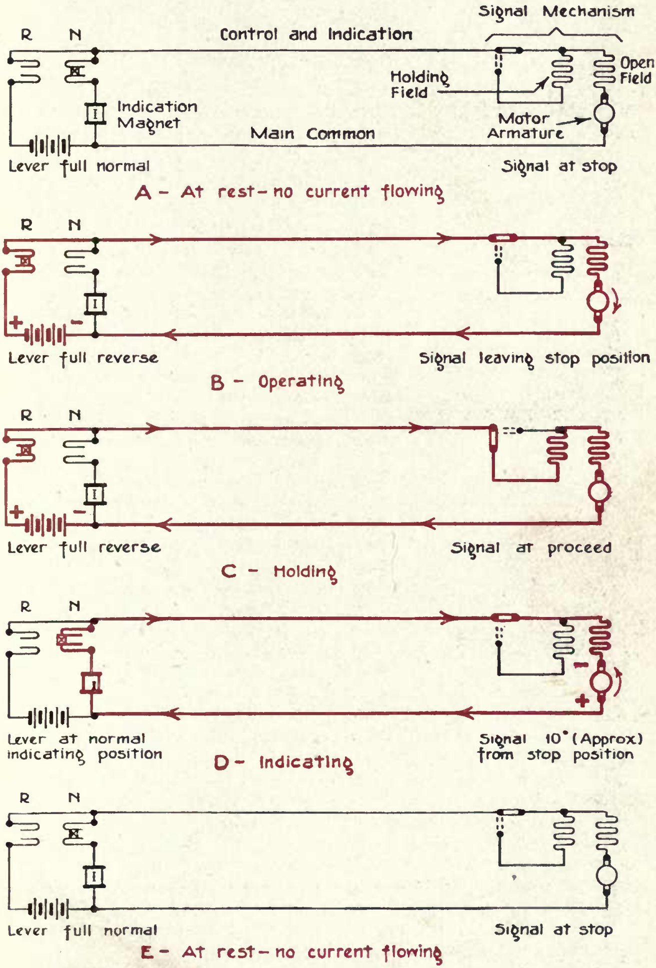


FIG. 8. SIMPLIFIED CIRCUITS FOR MODEL 2A, NON-AUTOMATIC, TWO POSITION SIGNAL

position. Just as the blade reaches the stop position the action of the circuit breaker connects the motor armature and operating field into their original closed circuit (Fig. 8D), in which is included the indication magnet. Due to its acquired momentum the motor (now a generator) produces an indication current in this circuit which permits the controlling lever to be moved to the full normal position (Fig. 8E).

It is universal practice to indicate the signal lever in the normal position only, this insuring that the signal blade is in the stop position before releasing any of the switch levers in the route governed. No safety features are sacrificed if the signal fails to assume the proceed position upon reversal of its controlling lever.

Dynamic Indication. The use of the dynamic indication as described above has the following advantages:

First — The indication is not secured from energy existent at the function prior to the movement of that function and dependent only on the closing of a single break in the indication circuit, as is the case in A. C. and battery indication systems; but being a dynamic current generated by the momentum of the motor, *it can be secured only after actual operation of the function.*

Second — The energy for the indication is developed at one end of the circuit and the indication magnet is located at the other; hence a cross between wires *prevents* indication, whereas in systems which use the battery in the interlocking station for indication a cross tends to *cause* indication.

Third — No extra power is required for indication.

Fourth — The indication current ceases automatically with the stopping of the motor and, therefore, no auxiliary devices or operations are necessary to cause it to cease.

Fifth — No additional wires are required for indication.

Sixth — The generated indication current automatically "snubs" the motor and causes it to stop without shock and without the use of buffers, springs, or auxiliary snubbing circuits.

Seventh — The indicating circuit is automatically checked as to its integrity every time an indication is received, and being a closed circuit of low resistance around the motor, it shields the motor while at rest from all foreign currents. This inherently provides the foundation for the simple and effective cross protection system employed with the G. R. S. electric interlocking.

Means for the Prevention of Unauthorized Function Movements

The cross protection system prevents the unauthorized movement of any switch, signal, or other function due to energy improperly applied to its circuit through a cross between wires, by cutting off current from the function in the event of such an occurrence.

As explained under "Dynamic Indication," all functions are normally on a closed circuit of low resistance. Connected in each of these circuits is a small polarized relay through which all operating and indicating currents must pass in a direction to maintain the relay's contact closed, while all currents from an unauthorized source must pass in the opposite direction thus instantly opening the contact. Through all these con-

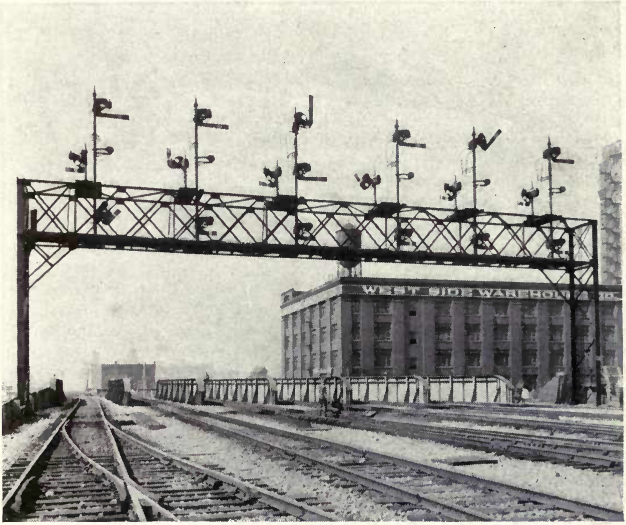


FIG. 9. MODEL 2A SIGNALS. CHICAGO TERMINAL, C. & N. W. R'Y

tacts in series is controlled the retaining magnet of an electro-mechanical circuit breaker, which is introduced into the power mains between the storage battery and the interlocking machine. Hence, a cross onto the circuit of a function at rest, by opening the contact of its polarized relay, opens the electro-mechanical circuit breaker, cuts power off from the interlocking machine and thereby prevents any improper movement of the function.

In a simple plant a single electro-mechanical circuit breaker is ordinarily installed, this preventing the movement of all functions at any time the circuit breaker may be open. Where traffic conditions warrant the increased expenditure, additional circuit breakers may be provided to permit of dividing the plant into as many sections as may be desired.

The design of the circuit breaker is such as to make it impossible for a leverman (thoughtlessly or through ignorance) to prevent it from performing its function.

Cross Protection. The cross protection secured with the G. R. S. electric interlocking system has the following advantages:

First — All contacts and connections depended upon for cross protection are either on closed circuit or are used for operation and indication, so that any failure of these contacts and connections, which would impair their usefulness as a cross-protective medium, also prevent operation and indication. Hence they are under a constant, automatic check without the use of any extra contrivances for this purpose.

Second — Wire insulation is not depended upon for cross protection. This system at certain installations has given years of safe operation with wire, the insulation of which does not measure up to the usual standard.

Third — The cross protective apparatus consists of the polarized relays and apparatus on the operating board; no wire or additional appliances are required outside of the station to secure this protection other than the simple apparatus already installed for the operation of the various functions.

Fourth — The switch and signal motors, being of low resistance, require a current of several amperes for their operation; therefore, a cross to produce the operation of any function must be of very low resistance. Thus it will be seen that the system is not sensitive to the effect of crossed wires. Notwithstanding this fact, an efficient system of cross protection is provided in the G. R. S. system.

Conclusion

The comparative value of different systems of interlocking may be accurately determined by a consideration of but four essential factors. These four factors must be present in any interlocking system to warrant its use. They are: *Safety, Facility, Reliability, and Economy.*

Safety.

The factor first demanding consideration is that of safety. This essential of an interlocking system overshadows all other considerations, and in the ideal system the *safety must be absolute*. The G. R. S. electric interlocking with dynamic indication provides a factor of safety that is the closest approximation to the ideal known to those skilled in the signaling art. This is verified by the statement made by a disinterested committee in an able report based on a study of various types of power interlocking systems, presented to the International Congress of Application of Electricity held at Marseilles, France, in 1908, this statement being worded as follows:

"The safety of an interlocking plant is dependent solely upon the existence of a positive, reliable indication of correspondence between the position of a lever and its controlled function. * * * the Taylor (G. R. S.) system meets even this requirement. In fact it insures absolute reliability of indication by employing the motor as a means for generating the required current as explained above — so that it is certain that the indication given cannot ever be due to defects in wiring. Then, this indication having been received in the interlocking station, it establishes a control which is permanently maintained by a source of energy located in the station. Moreover this permanent control utilizes identically the same circuit that is employed in the normal operation of the function; in consequence, the circuit used is one that must be maintained in good, operative condition for each movement of the function.

It will therefore be seen that by virtue of this arrangement, the Taylor (G. R. S.) system insures permanency of indication; that it is economical since it utilizes the operating source of energy located in the station, and that it is absolutely trustworthy since it is in no sense subject to any danger from crossed or grounded wires."

Facility.

The facility offered by any given interlocking system depends largely upon: first, the rapidity of operation of the individual functions, and second, its capabilities for permitting simultaneous operation of a number of functions. In such a system the amount of time required to move traffic is reduced to a minimum.

By incorporating the above two features in the design of the system, the G. R. S. electric interlocking fully meets all demands for facility of operation. This has been repeatedly proven by the performance of the system at points where the traffic conditions have imposed the most exacting operating requirements.

Reliability.

The reliability of an interlocking system is primarily dependent upon the fundamental principle underlying its operation, and in general it may be said, without fear of contradiction, that unless the principle is simple, it is not correct. The correct principle having been adopted, the reliability of the system then depends upon a proper design of each and every part of the devices used to put the principle into practice.

It is recognized that the principles of operation of the G. R. S. interlocking are correct, and the circuits simple to an extreme degree, no radical changes having been made in either since the introduction of the system. The parts of all apparatus are strong and rugged, and capable of performing their functions without undue wear and tear; furthermore, the design of all parts of the apparatus has been so very carefully perfected during some twelve years' experience that their form now represents the very best engineering practice.

As an example of the system's reliability of operation, records published by an important railroad covering a period of one year show a total of 2,615,406 switch operations, in which the number of imperfect operations were so few that they did not exceed one to every 186,814, and the total traffic detention for the year was only seventy and one-half minutes.

Economy.

Due to the correct design of the apparatus and resultant long life of same, the cost of renewals is practically negligible. This, together with the marked simplicity of the circuits, insures a cost of maintenance much less than in any other system of interlocking. The cost of operating also shows a corresponding economy, not only by the fewer number of men required for the operation of the power system as compared with the mechanical system, but also in the cost of power when compared with other power systems. Carefully kept railroad records show that the power cost is but one cent for 300 to 400 switch and signal movements.

A most minute analysis and extended description of the merits and advantages of any given system of interlocking fails to be convincing unless the truth of all the statements are thoroughly substantiated. That the above statements concerning the G. R. S. electric interlocking system must be true, is shown by the well nigh universal adoption of the system, both for large and for small installations.

Four hundred and forty installations have been made or are under contract on some eighty different railroads in all parts of the United States and Canada, a considerable number of plants also having been installed in Europe. On the basis that one interlocking lever in use for one year equals one lever year, the G. R. S. system now shows a record of 110,000 lever years.

The satisfactory operation of these installations, large and small, under widely varying conditions of both climate and traffic, is a most convincing demonstration that every demand for an interlocking system has been met in a most satisfactory manner by the G. R. S. electric interlocking.

SECTION II

G. R. S. ELECTRIC INTERLOCKING APPLIANCES

GIVING A DESCRIPTION OF THE APPLIANCES USED AND THEIR METHOD OF OPERATION

INTERLOCKING STATIONS

The Interlocking Station

THE interlocking station, from which the various switch and signal functions of the plant are operated, is usually a two-story building similar in appearance to those used at mechanical plants. The station does not require the same heavy construction used in mechanical work on account of the fact that the movement of the levers of the electric interlocking machine puts absolutely no strain on the building. It should be noted

Fig. 10. Hackensack Draw Bridge Interlocking Station. Erie R. R.

in this connection, however, that the frame building generally used in the earlier installations is of late years being largely supplanted by the more substantial brick or concrete structure.

Size of the Building

The station can be much smaller than that required for mechanical plants of the same number of functions due to the smaller size of the interlocking machine. The length of the building is usually determined by the size of the interlocking machine; the width, however, is generally in excess of that required for the machine, being increased to accommodate the table, lockers, etc., needed by the operator, and on the

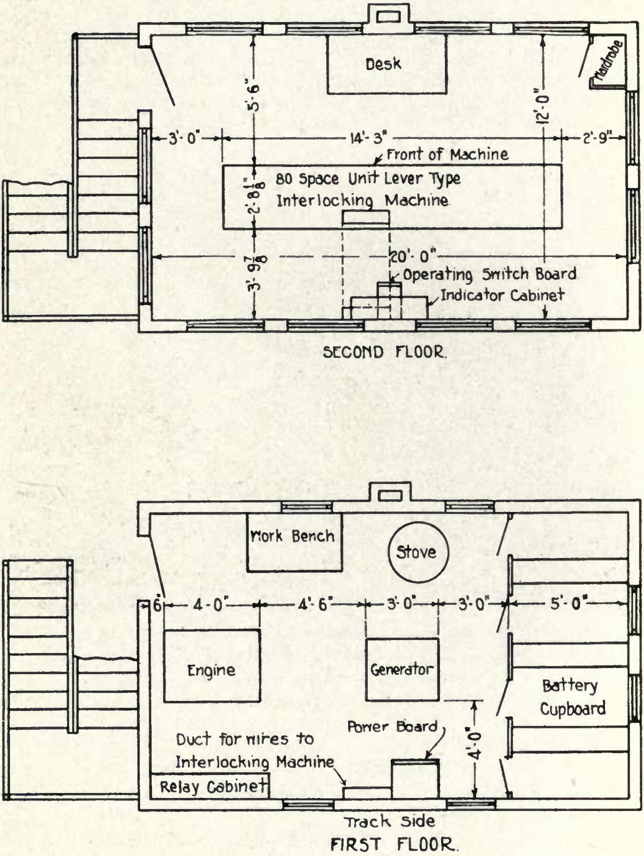


Fig. 11. Typical Plans of Interlocking Station for Eighty Lever Machine

larger installations to provide room for a train director and telegraph operator.

When it is desired to have shops and storerooms located in the interlocking station, the machine ceases to be the determining factor in the size of the building, unless the additional space for these rooms is secured by using a three-story building as in the case of the Lake Street Station shown in Fig. 13. It is also true that on small plants the location of the storage battery and power apparatus in the lower story of the station is apt to make it necessary for

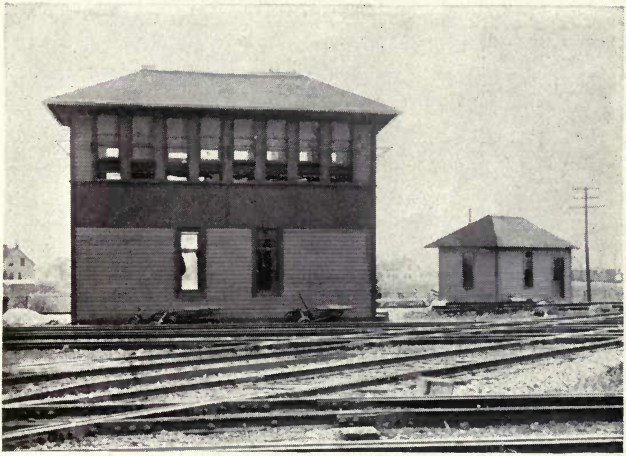


FIG. 12. SOUTH ENGLEWOOD INTERLOCKING STATION AND POWER HOUSE, C. R. I. & P. R'Y

the building to have larger dimensions than those required for the interlocking machine.

ARRANGEMENT OF APPARATUS

The different methods of arranging the apparatus in the station is shown by Figs. 11, 13 and 15, which may be taken as typical of small, intermediate and large sized stations respectively. By reference to these illustrations it will be seen that the general practice is to locate the interlocking machine, the operating switchboard and such accessory apparatus as track diagrams, indicators, etc., on the top floor, the storage battery in a room by itself on the lower floor, and the charging apparatus on the same floor with the battery or in a building separate from the interlocking station.

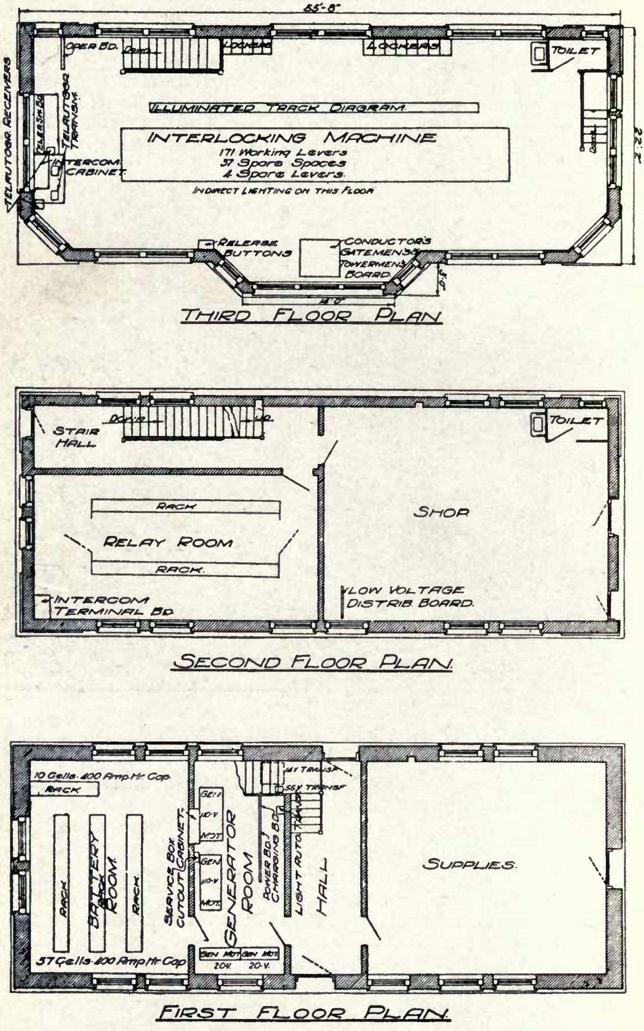


Fig. 13. Plan of Lake Street Interlocking Station. Chicago Terminal, C. & N. W. R'y

Points to be Noted

The design of the building should be such that the floors will be sufficiently rigid to properly support the machine.

Wherever possible the general practice is to have the operating room liberally supplied with windows to permit the operator to have a clear view of the tracks throughout the plant.

It is highly desirable that the conduits or ducts provided for the runs of electrical conductors about the tower should be

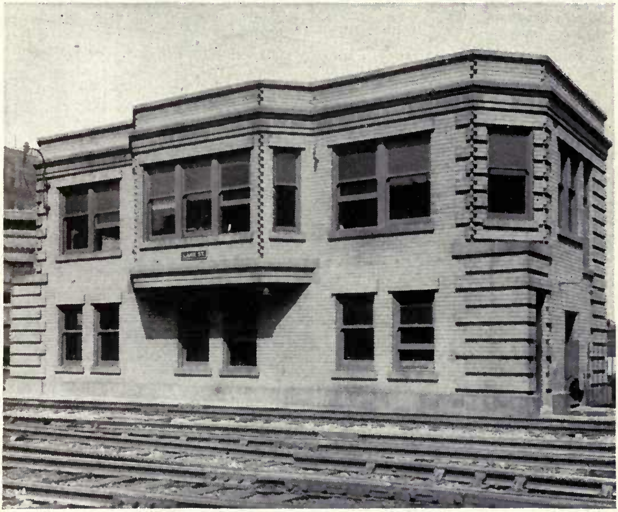


Fig. 14. Lake Street Interlocking Station. Chicago Terminal, C. & N. W. R'y

of sufficient capacity to have 25 per cent. spare space after all wiring is in place.

No special foundations are required for the apparatus used in an electric plant, except when the charging generator is driven by an engine, in which case a substantial foundation should be provided for the engine so that the building will not be subjected to any vibration during its operation.

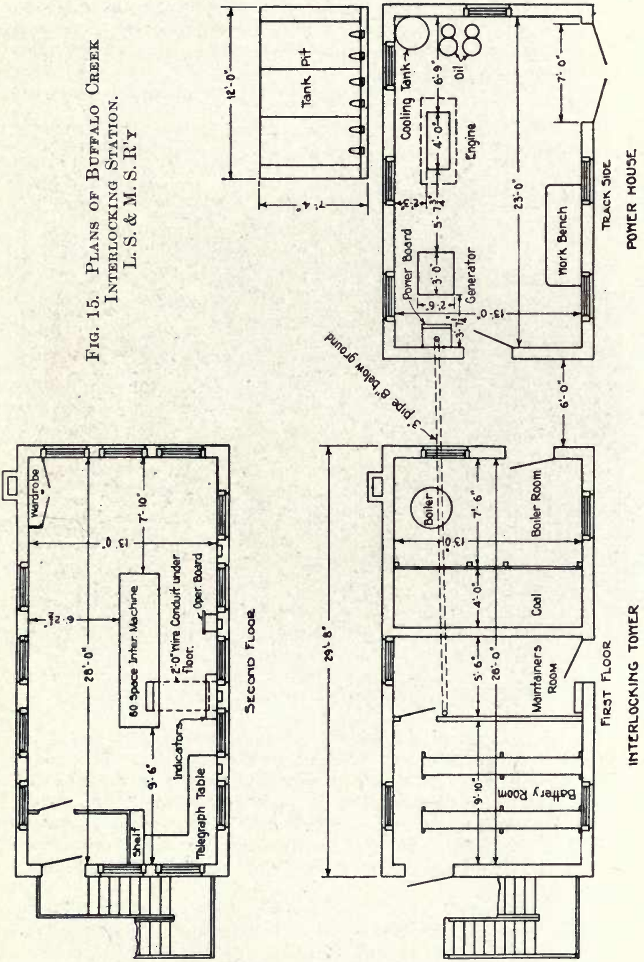


Fig. 15. Plans of Buffalo Creek Interlocking Station.
L. S. & M. S. R'y

POWER PLANTS AND SWITCHBOARDS

Composition

THE power equipment for the G. R. S. Electric Interlocking plants is usually composed of a storage battery, suitable means for charging the battery, a power switchboard and an operating switchboard.

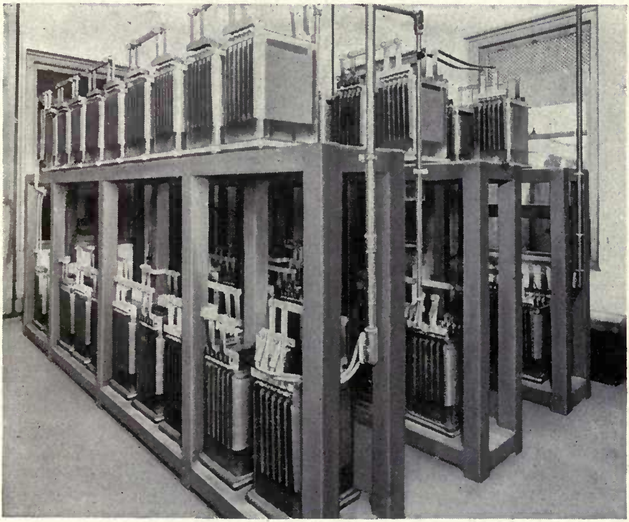


Fig. 16. Interlocking Battery (400 Ampere Hours) Installed on Battery Racks

Location

The location of the units which compose the power plant varies considerably on different installations. The operating switchboard is always located in the operating room, being placed whenever possible in such a position that its meters and indicating lamp are in full view of the leverman when manipulating the levers of the machine. The storage battery is ordinarily located on the first floor of the interlocking station. The power switchboard and charging apparatus at many installations are placed in a room adjacent to that occupied by the battery, although building restrictions or the need of space for workrooms or offices often make it necessary to house this apparatus in a building separate from the interlocking station.

Batteries

The interlocking battery usually consists of one set of storage cells having a potential of 110 volts. A second or duplicate battery is furnished on a few of the larger installations to insure sufficient power for any possible emergency.

Fig. 17. Interlocking Battery (120 Ampere Hours) Installed in Battery Cupboard

The capacity of the battery used should be based on the number of function movements between battery charges and the current used for all auxiliary apparatus.

The battery as usually installed comprises fifty-five lead type storage cells. When long runs of conductors between the battery and interlocking machine are necessary, one or more cells are sometimes added to the battery to compensate for the voltage drop which occurs in the conductors whenever several switch functions are operated at the same time.

This may also be taken care of by using wires of larger carrying capacity than would otherwise be necessary.

Low voltage batteries are frequently installed to operate annunciators, indicators, relays and electric locks, and occasionally to serve the track circuits of the interlocking plant. Operating the relays, indicators, etc., from a low voltage battery usually proves more economical than to take current for that purpose from the main battery.

Charging Apparatus

The charging of the battery is generally accomplished by means of a shunt wound generator driven by an electric motor or gasoline engine. The generator should be capable of de-

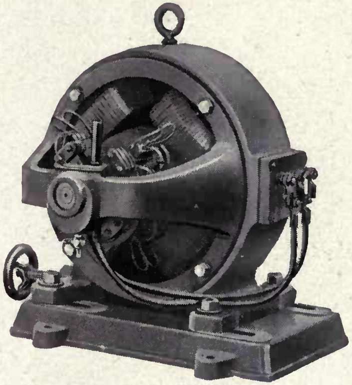


Fig. 18. G. R. S. D.C. Generator

livering the desired current at any voltage from 110 to 160, the current output being determined by the charging rate recommended for the batteries installed. In the event of the generator being used to supply current for lighting, either regularly or in case of emergency, the additional capacity required for the purpose should not be overlooked.

When the generator is located at some distance from the battery it is necessary to take care of the voltage drop due to the resistance of the charging circuit, either by increasing the size of the conductors or by using a generator having a higher voltage rating.

Whenever current of suitable voltage and from a reliable source can be secured at reasonable rates, its use is recommended. The motor-driven generator, referred to above, is usable with either alternating or direct current, the generator being shaft or belt connected to the motor as proves most convenient. If the current supply is direct, a charging rheostat can be used for the battery charging, or if alternating, a rectifier employed.

Charging rheostats, having no moving parts, are the simplest and most reliable of the different types of apparatus which can be used in this work. They are, however, very much less efficient than other battery charging devices, and therefore should not be used when the cost of power is an item to be considered.

Motor generator sets are compact, reliable and, furthermore, highly efficient. When used on this type of work, they can

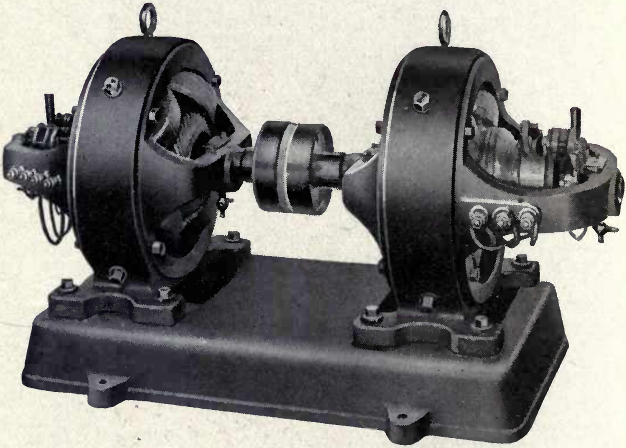


Fig. 19. G. R. S. D. C.–D. C. Motor Generator Set

be designed for operation on voltages as high as 550, the lower voltages, however, being recommended as most satisfactory from the maintenance standpoint.

Power Switchboard

The power switchboard most frequently furnished (Fig. 20) is arranged to control the charging of one set of storage batteries from an engine driven generator, and in conjunction with the operating board to control the power delivered to the interlocking machine.

It may be placed in any accessible position in the power house, convenience in making the runs of electrical conductors between the power board, the charging apparatus and the battery being considered.

The size and arrangement of the power board for different installations is determined by the method of charging the batteries, the number of sets and voltage of each battery, and whether or not the board is to control any electric lighting which may be installed at the plant. If a motor generator set is to be controlled an additional panel for its starting device can be mounted on the switchboard frame.

When the track circuits in the plant are operated from

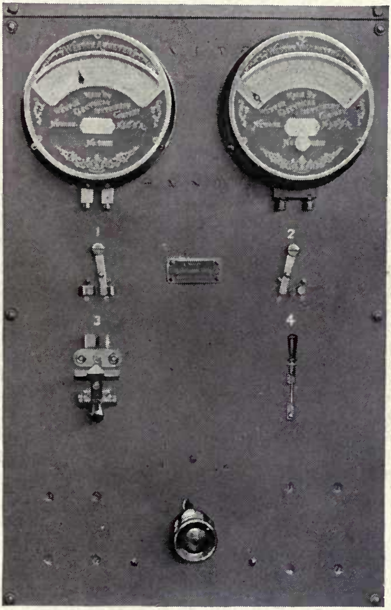


FIG. 20. STANDARD POWER SWITCHBOARD FOR ONE GENERATOR AND ONE 110 VOLT BATTERY

storage batteries or from transformers located in the interlocking station, it is customary to serve these track circuits through switches on the power board.

On the switchboard shown in Fig. 20 are mounted a no-voltage, reverse-current circuit breaker, a field rheostat, a voltmeter, an ammeter, suitable switches, and the necessary fuses.

The no-voltage, reverse-current circuit breaker, which is placed in the charging circuit between the generator and battery, is designed to open in case the voltage of the generator falls below that of the battery. By means of this arrangement the charging of the battery can be accomplished without the constant attention of the maintainer, this permitting inspections to be made at such intervals as may be most convenient.

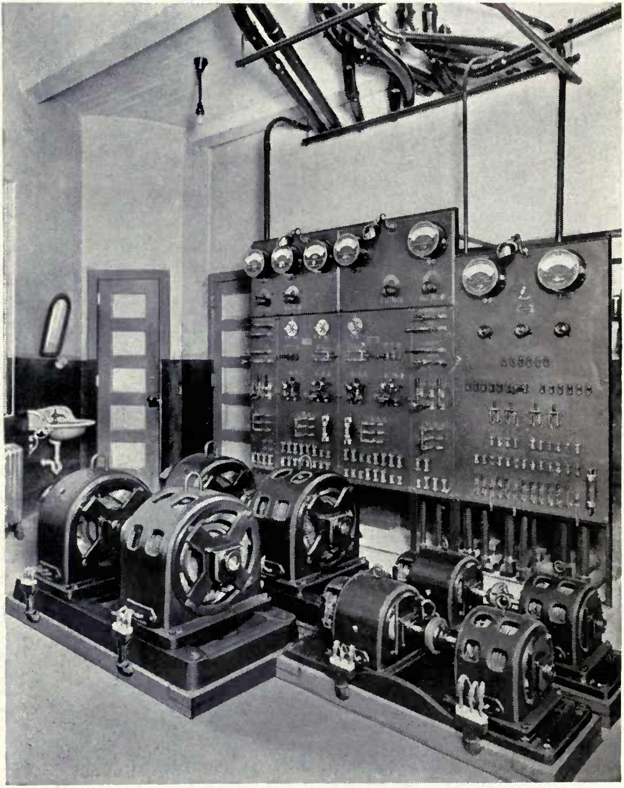


Fig. 21. Power and Distributing Switchboards and Motor Generator Sets. Lake Street Interlocking Plant, Chicago Terminal, C. & N. W. R'y

The rheostat connected in series with the generator field permits the generator voltage to be accurately regulated.

The voltmeter and ammeter are arranged to give readings on the charging or discharging circuits as desired.

The simplified diagram (Fig. 22) shows the principles of the circuits used in connection with this board and clearly

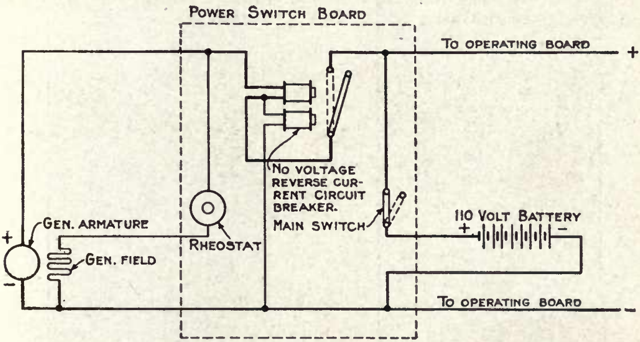


FIG. 22. SIMPLIFIED CIRCUITS FOR POWER SWITCHBOARD

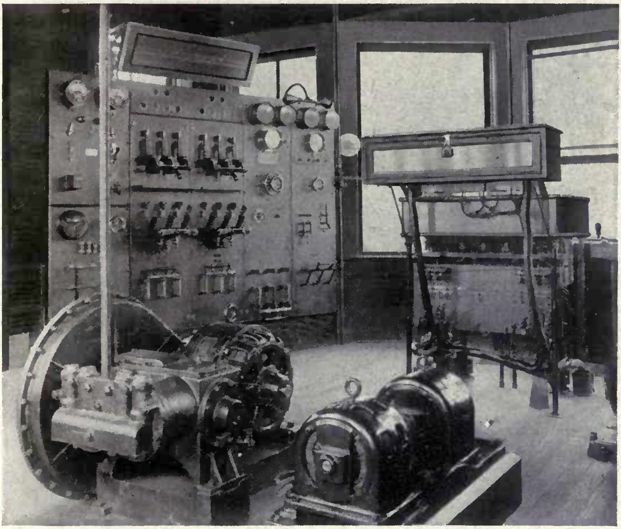


FIG. 23. OPERATING ROOM AT OREGON SLOUGH
DRAW BRIDGE. N. P. R'Y
Combination power and operating switchboard at extreme left.

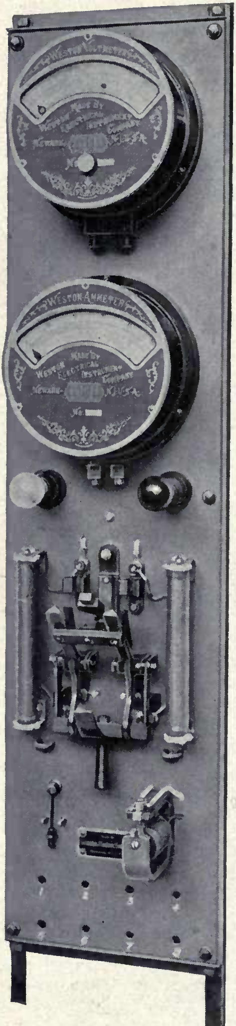


Fig. 24

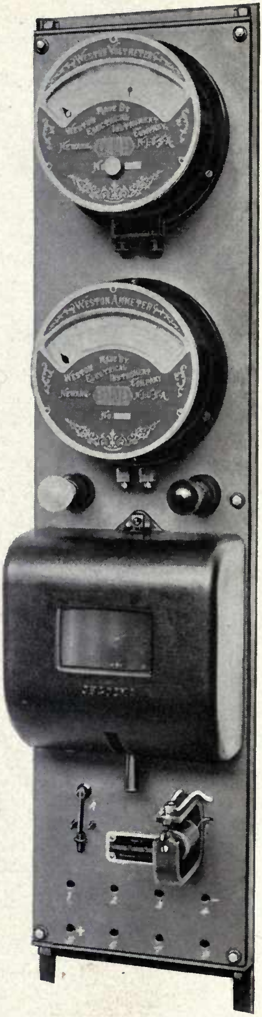


Fig. 25

Standard Operating Switchboard

illustrates the functions of the various devices essential to the power control.

Operating Switchboard

The operating switchboard shown in Figs. 24 and 25 is typical of those furnished where all functions in the plant are to be controlled through a single circuit breaker. When the plant is sectionalized the board must be equipped with additional circuit breakers, one being required for each section.

The apparatus mounted on the board illustrated consists of the cross protection circuit breaker with its indicating red lamp, a polarized relay, a ground lamp and switch, a voltmeter and an ammeter. A panel for lighting switches can be bolted to the switchboard frame when it is desired to control the lighting from this point.

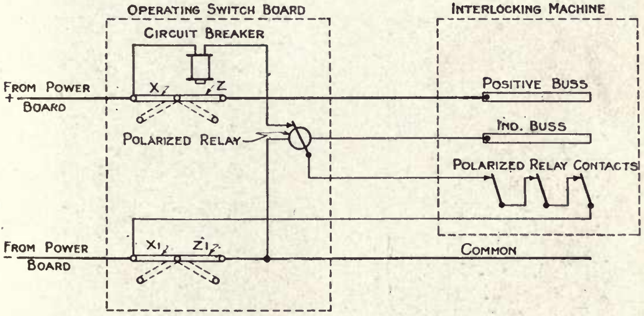


Fig. 26. Simplified Circuits for Operating Switchboard
Lettering of the cross protection circuit breaker contacts corresponds with the lettering used in Figs. 64 and 66.

The cross protection circuit breaker, introduced into the power mains leading to the interlocking machine, is so controlled that in the event of current being improperly applied to the circuit of any function at rest, the circuit breaker will open and cut all power off from the system. The red lamp is arranged to be lighted at this time to call the leverman's attention to the fact that the circuit breaker has opened.

The design of the circuit breaker and its cover is such that it cannot be prevented from opening should a cross occur, nor can it be restored to its operating position except by means of the restoring handle.

The simplified circuit (Fig. 26), in which is included only the apparatus essential to the circuit breaker control, shows the retaining magnet of the circuit breaker controlled through the polarized relay on the switchboard and those on the interlocking machine in such a manner, that, should any of them reverse their position, the circuit breaker will immediately open.

The polarized relay on the switchboard is to guard against the effects of an accidental cross between the positive and indication buss bars on the interlocking machine, the relay operating in the same manner as the polarized relays which protect the various switch and signal functions.

By means of the ground lamp and switch, the plant may be tested for positive and negative grounds.

The voltmeter indicates the battery voltage at the terminals of the interlocking machine.

The ammeter shows the current taken by the various functions when they are being operated. By observing this current reading the operating conditions of each function can be determined. This is particularly true of the switch functions, the need of oiling or adjustment being readily detected from the abnormal amount of current or length of time required for their operation.

ELECTRIC INTERLOCKING MACHINES

Interlocking Machine Control

THE interlocking machine used with the G. R. S. system controls the movement of switch and signal functions through the medium of suitably interlocked levers, which with their guides, indication magnets and circuit controllers, are mounted in the common frame as shown in Fig. 27. General practice is to furnish an individual lever for each signal

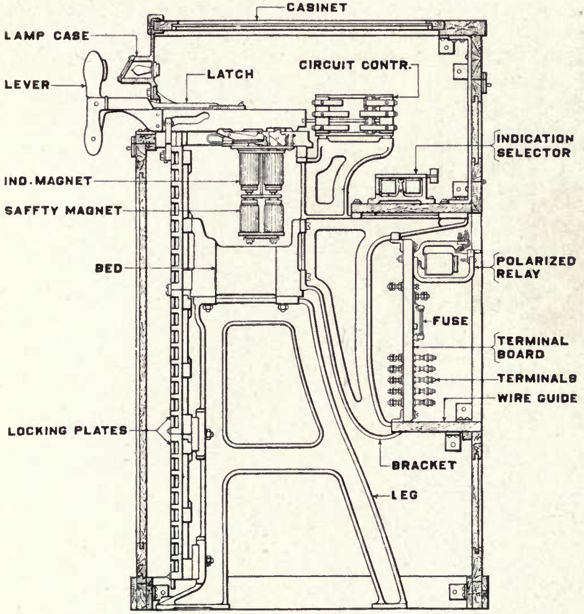


Fig. 27. Cross Section of Model 2 Unit Lever Type Interlocking Machine

arm and for each switch function, except where two switches are to be operated together, in which case their levers are rigidly connected and operated as a unit.

The design of the machine and the controlling circuits is such that the following features essential to safe operation are afforded:

First — No lever can be moved from a given position if any other lever, mechanically interlocked therewith, is in such a position that its controlled function will conflict with the function to be moved. Furthermore, due to the mechanical locking being of the preliminary type, before the given lever can be moved from its position, all these conflicting levers will be locked against movement until such time as it is proper for them to be released.

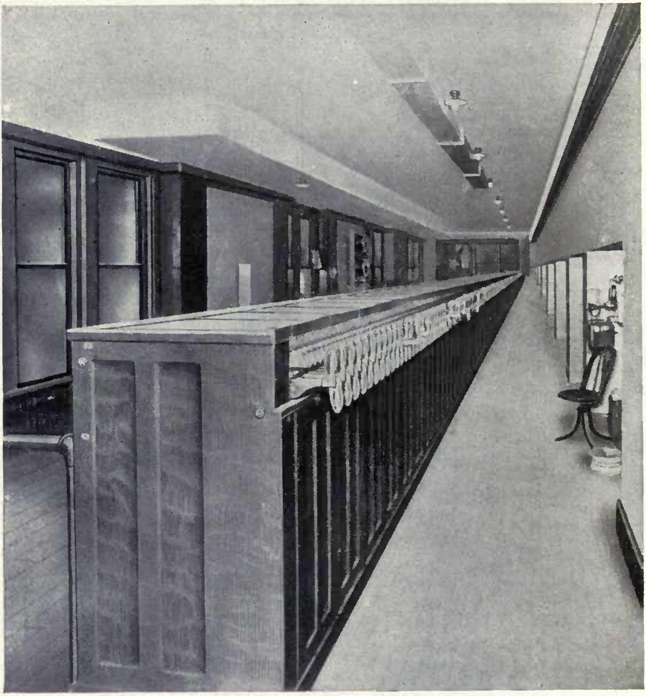


Fig. 28. Four Hundred Lever Interlocking Machine, Model 2 Unit Lever Type. Grand Central Terminal, Tower "A," N. Y. C. & H. R. R. R.

Second — The full movement of any switch lever cannot be completed until the controlled function has moved to, and been locked in, the position corresponding with that of the lever. In the case of a signal lever this correspondence of position is required only on the normal movement of the lever, which can be completed only after the signal arm has assumed the stop position.

Third — Each function when in a position of rest is protected against any unauthorized operation which might otherwise be accomplished through current being wrongfully applied to its controlling circuits.

In explaining the operation of the lever, its movement is considered as being divided into three parts, the preliminary, intermediate and final. In order that the reader may not be confused on account of the lever operation having previously been described as being performed in two movements (page 18), it is desired to point out that the pre-

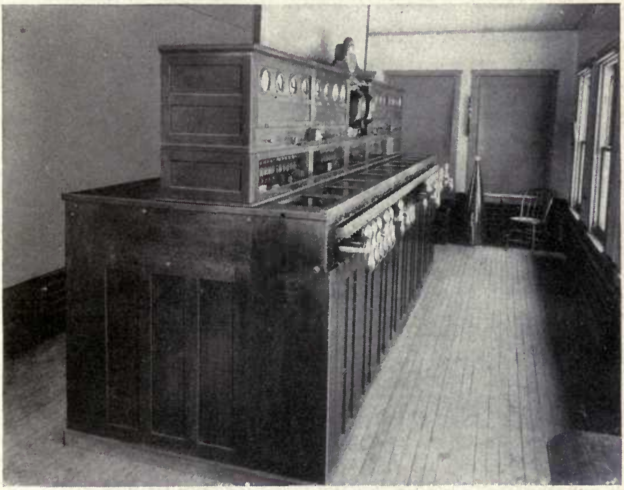


FIG. 29. MODEL 2 UNIT LEVER TYPE INTERLOCKING MACHINE. COLLINWOOD INTERLOCKING PLANT, L. S. & M. S. R'Y. (See Fig. 32)

liminary and intermediate part usually constitute one continuous movement, it being necessary to separate them, however, when considering the detail operation of the lever.

The following description is based on the operation of the switch lever. Each of these levers is provided with a cam slot, by means of which intermittent motion is transmitted to its respective tappet bar and thence to the cross locking. In Fig. 30 the dotted circles 1 to 5 in the cam slot indicate the positions of the locking tappet roller which correspond with the like numbered position of contact block Z. In the preliminary movement of the lever from position 1 to 2, the locking tappet is moved through one-half of its stroke, this movement locking all levers which conflict with the new position of the lever in question; in this movement no change whatsoever is made in the operating circuits. During the intermediate part of the travel from positions 2 to 4, the tappet bar remains stationary and the contact block Z is moved out of engagement with springs YY and into contact with springs XX as shown in Fig. 31, this setting up the circuits for the operation of the function. The lever is held at this point, (position 4), through the mechanical design of the lever proper, until such time as the function having moved to a corresponding position, generates the dynamic indication current which effects the release of the lever and permits its movement to position 5. During this final movement from position 4 to 5, the stroke of the locking tappet is completed, thereby unlocking all levers which do not conflict with the new position of the operated lever.

The method by which the lever is prevented from completing its stroke, until the controlled function has moved to a corresponding position and has sent in its indication, is illustrated by the following: in moving from positions 1 to 2 projection M on the lever coming against projection K on latch L, causes the latch to assume the position shown in Fig. 31. This brings projection J on latch L into the path of tooth Q on the lever. In moving from position 2 to 4, tooth Q engages with cam N, rotating it to the position shown in Fig. 31. As it passes the central position (shown dotted in Fig. 31) it comes in contact with dog P which is forced under latch L, thereby locking the latch L in the position assumed. The lever is stopped at position 4 by tooth Q coming against projection J on latch L as previously explained. The indication current, by flowing through magnet I, lifts armature T which causes plunger R to strike dog P and trip it out from under latch L. The latch L then drops to the position shown in Fig. 30, thereby releasing the lever and permitting its final movement to be accomplished.

The movement of the lever from reverse to normal is performed in a similar manner to that described above. Attention is called to the fact that once the lever has been moved to, or beyond, position 3, it can neither be moved forward beyond position 4 nor back beyond position 2 without the receipt of an indication.

The movement of the signal lever is identical with that of the switch lever except that no electrical indication is required during the reverse movement, the lever not being checked at position 4 due to a change in the design of dog P, which is mechanically tripped at this point from under latch L by cam N. The mechanical locking insures that before a signal can be given for any route, that all switch and derail functions in the route are thrown to the proper positions and locked in that position, and that all opposing signals are in the stop position. No changes can be made in the position of any of these functions until the lever, controlling

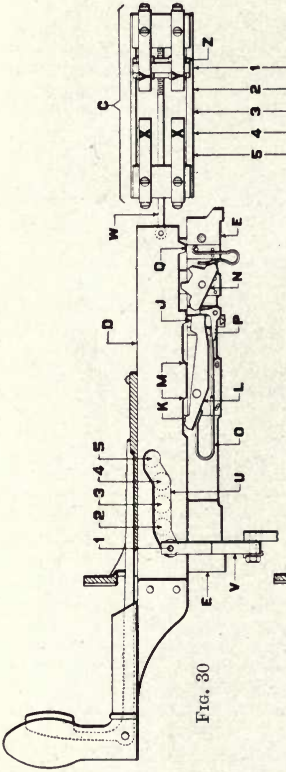


Fig. 30

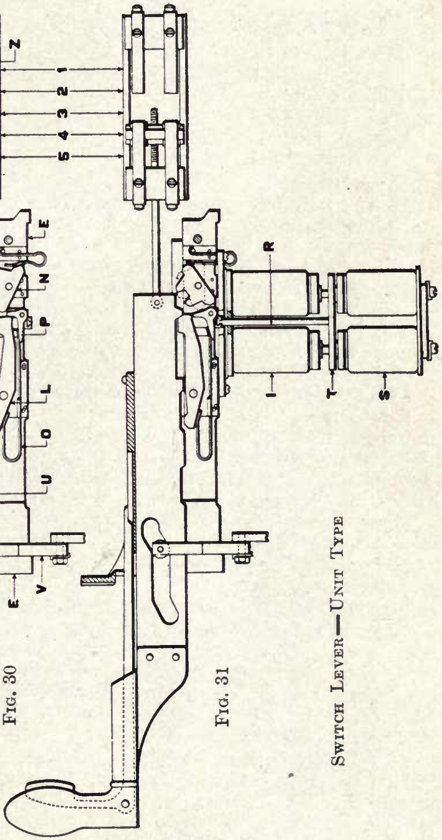


Fig. 31

Switch Lever—Unit Type

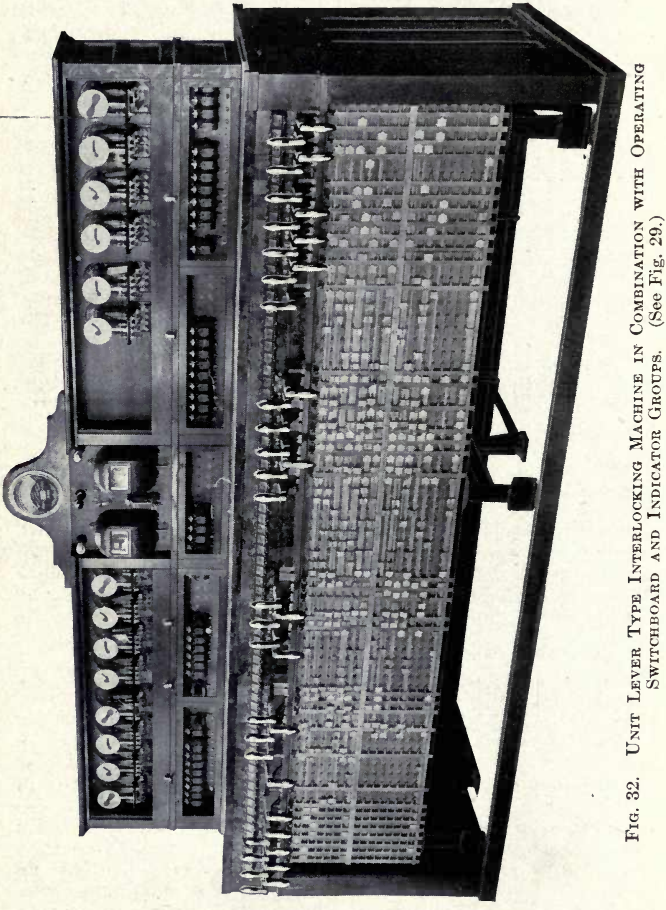


Fig. 32. Unit Lever Type Interlocking Machine in Combination with Operating Switchboard and Indicator Groups. (See Fig. 29.)

the signal displayed at proceed, has been replaced to its full normal position.

The various functions are protected against unauthorized movement by means of the cross protection system, as described on page 89, the individual polarized relays which furnish this protection being mounted on the terminal board of the interlocking machine. All lever contacts which form a part of this cross protection scheme are used in the operation of the function, and hence are checked as to their integrity with every complete operation.

Model 2 Unit Lever Type Interlocking Machine

The description of the interlocking machine following is based on the Model 2 Unit Lever Type (Fig. 27) which is considered the standard machine. This machine is a development of the Model 2, still widely used, a cross section of this being illustrated by Fig. 137. Modifications of the Unit Lever Type machine are shown by Figs. 32 and 138, the latter being furnished when more contacts are required for supplementary circuits than can be secured on the regular lever circuit controller.

The standard machine essentially comprises the frame, the levers with their guides, indication magnets and circuit controllers, the locking plates and locking, the terminal board, and the machine cabinet.

Frame.

The frame work, which consists of a bed, supporting legs and brackets, is substantially constructed, thereby insuring that all inter-related mechanical parts are maintained in their proper relative positions. For machines having a capacity up to forty-eight lever spaces, the bed is cast in one unit. Machines of over forty-eight levers are made up of various combinations of beds bolted together to give the required lever spaces.

Locking Plates and Locking.

The locking plates are securely attached to the front of the machine frame, being furnished in tiers to a maximum of three, the number depending upon the amount of locking required at each individual plant. A fourth tier can be furnished when necessary by using a special form of leg, which has sufficient height to accommodate the extra tier of plates.

The locking plates are designed with vertical and horizontal slots, the locking tappets, one of which is attached to each lever, being fitted in the vertical slot directly beneath its respective lever. Movement is transmitted from the lever through the medium of the tappets to the cross locking, which slides back and forth in the horizontal slots of the locking plates. The dogs used in the cross locking can be furnished screwed or riveted to the locking strips, as desired.

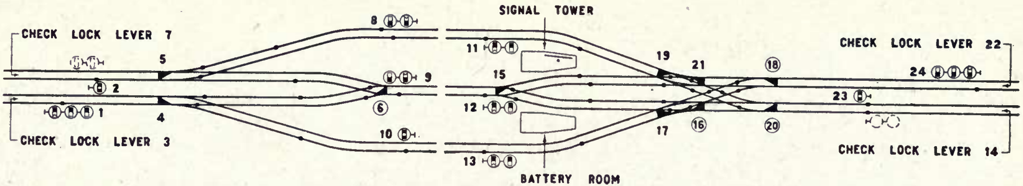


FIG. 33. TRACK PLAN. THIRTY-THIRD STREET STATION, HUDSON TUNNELS, H. & M. R. R.

LOCKING SHEET FOR ABOVE TRACK PLAN

Lever	When	Locks	Lever	When	Locks	Lever	When	Locks
1	. . . .	4–(4)–10	7	Check Lock Lever		14	Check Lock Lever	
	4 – 15 –19, . .	23	8	. . . .	7 – 5	15		
	4 –(17), ...	24	9	. . . .	5 –(5)	16		
	(4), ...	9–5		5, ...	(4) – (3)	17		
	(4)–(21)–17, . .	24		(5), ...	7	18		
	(4)–(15)–19, . .	23	10	. . . .	(3) – 4	19		
2	. . . .	5–(5)–8	11	. . . .	19 –(19)–(21)–24–17	20		
	5 – 21 –17, . .	24		19, ...	(22)	21		
	5 –(19), . . .	23		(19), ...	23 – 14	22		
	(5), ...	9	12	. . . .	15 –(15)– 17 –19	23	. . . .	19–(19)–17
	(5)–(21)–17, . .	24		15, ...	(21)– 24 –(22)		19, ...	15–(15)
	(5)–(15)–19, . .	23		(15), ...	23 – 14	24	. . . .	17–(17)–19
3	Check Lock Lever		13	. . . .	17 –(17)– 15 –19		17, ...	21–(21)
4				17, ...	23 – 14		17–(21), ...	15
5				(17), ...	(22)– 24		(17), ...	15
6								

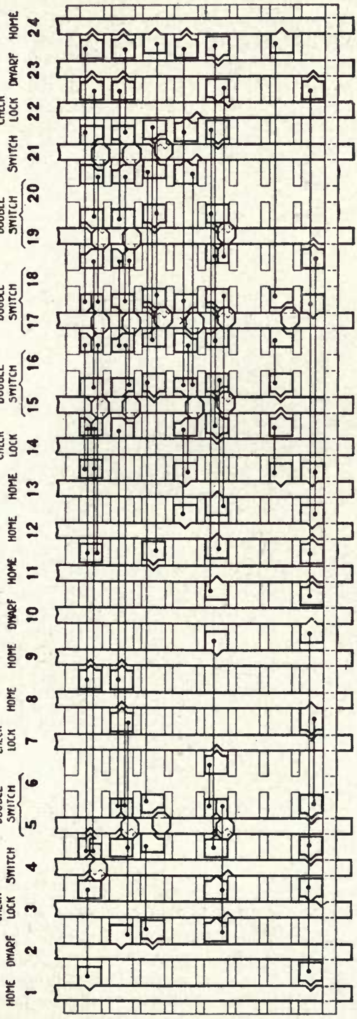


FIG. 34. DOG CHART FOR LOCKING IN MODEL 2 INTERLOCKING MACHINE. THIRTY-THIRD STREET STATION, HUDSON TUNNELS, H. & M. R. R.

Each tier of locking has eight of these horizontal slots, and each of these slots is capable of accommodating four locking strips, thus giving this type of locking bed a large capacity as is indicated by the fact that the locking required for extremely large and complicated layouts has been readily accommodated in three tiers. In fact, it is a very rare occurrence that the fourth tier is ever required.

By using locking of the vertical type no additional floor space is required beyond that ordinarily taken by the machine,

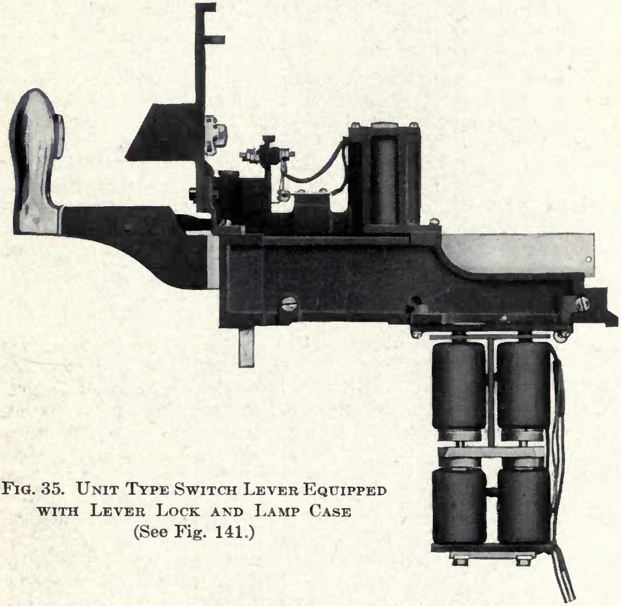


FIG. 35. UNIT TYPE SWITCH LEVER EQUIPPED WITH LEVER LOCK AND LAMP CASE (See Fig. 141.)

no matter how many tiers are provided. This type of locking also permits ready access for inspection or cleaning, or making any changes which may be required.

Levers.

Each lever with its guide, indication magnet, controllers, etc., comprises a complete unit in the interlocking machine, the design being such that the unit may be removed or replaced in the machine without moving the lever tappet from the normal position or disturbing adjacent levers in any way. The lever guide is jointly supported by the top edge of the locking plates and a longitudinal bar fastened to the brackets, the circuit controllers being screwed to two other bars which are supported by this same bracket.

The circuit controller with which each lever is equipped can be provided with a maximum of five tiers of contacts, controlling five normal and five reverse independent circuits, which affords more contacts than are ordinarily desired for supplementary circuits.

The space required for each unit is but two inches, this permitting the complete machine to occupy less space lengthwise than other existing types of interlocking machines, either power or mechanical, having the same lever capacity.

Lamp Case and Number Plate.

The combined lamp case and number plate is mounted above each lever, its base being attached to a plate screwed to the top of the lever guide, and its top to the cabinet frame. The number plate is designed to lie at an angle which renders it readily visible to the operator when manipulating the levers. Bulbs and sockets are furnished only for such levers as may be specified, generally being used in conjunction with some type of electric locking to give an indication as to whether the lever may be moved or not. If desired, a double lamp case can be furnished to give two separate indications.

Terminal Board.

The slate terminal board is securely attached to the brackets on the rear of the machine. On this board are mounted the switch and signal buss bars, the individual polarized relays, fuses for the operating circuits, and the terminal posts for all wires which form a part of any of the interlocking machine circuits. The wires running from the binding posts to the various contacts, etc., in the machine are made up as formed leads, thus presenting a neat and uniform appearance; it also simplifies any "connecting up" incidental to the field installation of additional levers to the machine.

All fuses and terminal posts on the board are located directly beneath their respective levers, the terminal posts being lettered in correspondence with the circuit plan to indicate the wires which are to be attached to each post.

Polarized Relay.

The polarized relay which is illustrated by Fig. 36 is mounted on the terminal board directly beneath its lever. It is provided with a soft iron core which lies lengthwise between the poles of a permanent magnet, the design being such that current passing in one direction through a winding on the soft iron core, tends to hold the relay armature normal and contact closed, while current in the opposite direction immediately reverses the armature and thereby causes the contact to open. An extension of the armature is provided for convenience in replacing it to the normal position should it for any cause be reversed.

Indication Selectors.

The indication selectors, one of which is used in connection with each switch function, are mounted on a shelf supported by a bracket on the rear of the interlocking machine. The selector is simple in design, consisting of two electro magnets and a contacting armature which throws in one direction when the lever is reversed and in the other when the lever is put normal.

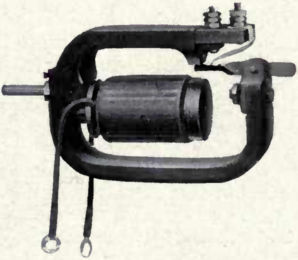


Fig. 36. Polarized Relay

Interlocking Machine Accessories

Lever Locks.

The electric lever lock, illustrated by Fig. 35, may be applied to any lever in the machine, its winding being designed for operation on direct or alternating current. The lock is designed to be mounted on the top of the lever guide, locking the lever in any required position by means of a solenoid plunger, which, when the lock is de-energized, drops into a notch cut on the top of the lever. These notches may be arranged so that the lever will be locked in any position as required by the electric locking circuits used at the plant. The circuit for the lock coil is broken through a contact spring actuated by the lever latch, the lock therefore not consuming energy except when lever is to be moved.

Mechanical Time Release.

The mechanical time release furnished with the G. R. S. interlocking is illustrated by Fig. 37, and the method of its application to the machine by Fig. 38. It is used in connection with electric locking circuits to effect the release of a route in case of emergency, this being accomplished by manipulating the release to its full reverse position, at which point a contact is closed to pick up a stick relay, energize a lever lock, etc. The first movement of the device towards the reverse position, however, mechanically locks, in their given positions the levers controlling all functions in the route, this necessitating that the release be returned to its normal position before the route can be changed. The operation of the release to the reverse position and back to the normal position affords a time interval of about two minutes.

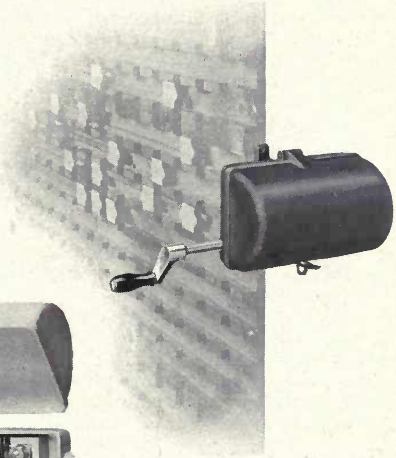


FIG. 38

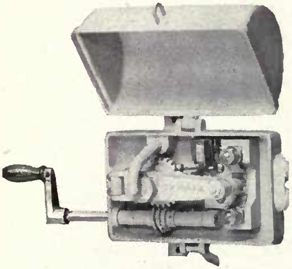


FIG. 37

MECHANICAL TIME RELEASE

SWITCH OPERATING MECHANISMS

Switch Machine Control

SWITCH and derail functions in the G. R. S. system are operated by switch and lock movements, driven by series wound direct current motors.

These switch mechanisms, each of which is under the control of a lever in the interlocking machine, require for their operation two wires only, one being used for the normal and the other for the reverse operation. These same wires are used for indicating purposes, the normal control wire being used for the reverse indication and the reverse control for the normal indication. The circuit is connected to main common at the switch location.

When the lever is moved to a position to cause the operation of the switch mechanism (see dotted position of lever contacts in Fig. 39), current is taken from the positive buss bar through the safety magnet, indication selector, lever contacts and the control wire, through the switch motor and to common. This causes the desired movement of the switch machine, which performs the following functions in the order given:

First — The detector bar is raised and the switch unlocked,
Second— The switch points thrown,
Third — The switch points locked and the bar lowered,
Fourth and Lastly — Current is cut off from the motor, and the terminals of the motor armature reversed for indication purposes, this leaving the motor properly connected for the next movement.

The motor is now on a closed circuit which includes the indication magnet. Due to the momentum acquired during the switch operation, the motor armature continues on several revolutions for the generation of the momentary current which energizes the indication magnet and thereby permits the final movement of the lever to be completed.

The operation of the switch machine in the opposite direction is accomplished in the same manner as described above.

The changing of the motor connections at the end of the switch operation is effected by the mechanical shifting of the contact block in the pole changer (Figs. 42 and 46). In addition to being mechanically operated, this contact block is under the control of two sets of solenoid magnets, so that should the switch fail to complete its movement the controlling lever may be shifted, and, through the energizing of one set of the magnets, cause the pole changer to set up the circuit for the operation of the switch in the opposite direction. This places the mechanism so under the control of the leverman that should the switch points be blocked with snow, ice, etc., the points may be worked back and forth, frequently dislodging the obstruction, thereby permitting the desired movement of the switch to be completed.

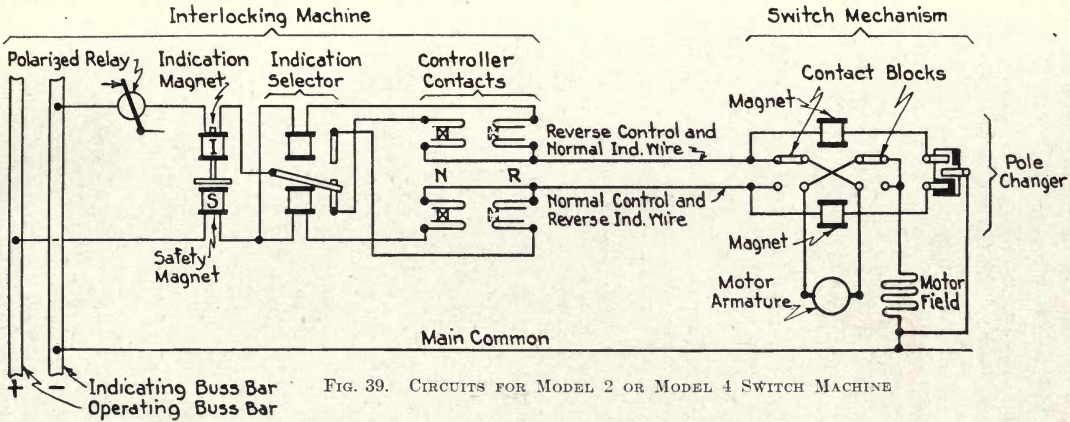


FIG. 39. CIRCUITS FOR MODEL 2 OR MODEL 4 SWITCH MACHINE

SAFEGUARDS

The switch mechanism is at all times safeguarded from false operation and its lever from improper indication in the following manner:

With the switch lever in either its normal or reverse position and the function at rest, the unauthorized movement of such function due to currents wrongfully applied to its circuit is prevented by the cross protection system as described on page 89.

While the lever is being moved to a position to cause operation of the switch it is guarded from premature (false) indication by the mechanical design of the lever itself.

During the time when current is flowing through the lever contacts for the operation of the function, the safety magnet insures against the possible receipt of an improper indication due to an accidental cross between the control wires of the function. The safety magnet is mounted beneath the indication magnet with the indication magnet armature resting on its poles, some distance from the poles of the indication magnet. The safety magnet coils are so connected in the operating circuit that the whole operating current flows through them, hence any current flowing through the indication magnet, due to a cross between the control wires of the function, cannot exceed the current through the safety magnet. The winding of the safety magnet is proportioned so that in conjunction with the above two features, the indication magnet armature cannot be lifted by current resulting from a cross as stated above.

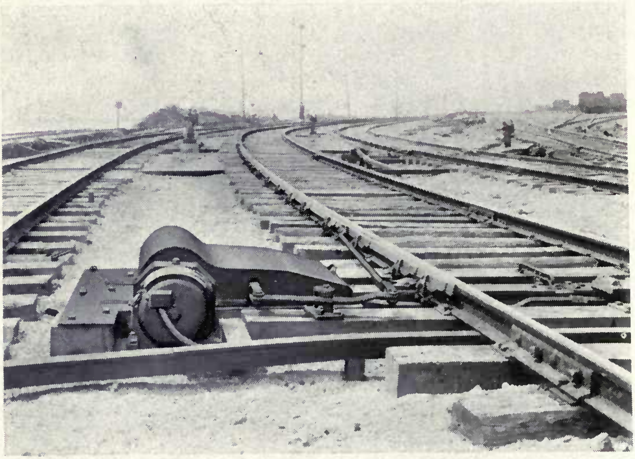


Fig. 40. Model 2 Switch Machine. Buffalo Creek Interlocking Plant, L. S. & M. S. R'y

From the time when the lever is moved to the new operating position until the movement of the switch machine is completed, the indication selector further insures against the possible receipt of any improper indication, being so connected that the operating current will attract its armature and close the contact for the reverse indication only when the lever is moved reverse, and the contact for the normal indication when the lever is moved normal. It should be noted that both the indication selector and safety magnet coils are connected in series with the control circuit, therefore if the circuit through them is not intact, operation of the function will be prevented.

When the motor operating circuit is opened by the action of the pole changer, after the switch has been locked in position, current ceases to flow through the safety magnet. Therefore the armature of the indication magnet is no longer held down, this permitting the indication to be effected upon receipt of the dynamic current generated by the motor.

The mechanism is now at rest protected against any unauthorized movement in the same manner as before the controlling lever was reversed.

Owing to the design of the operating circuits, the magnetic

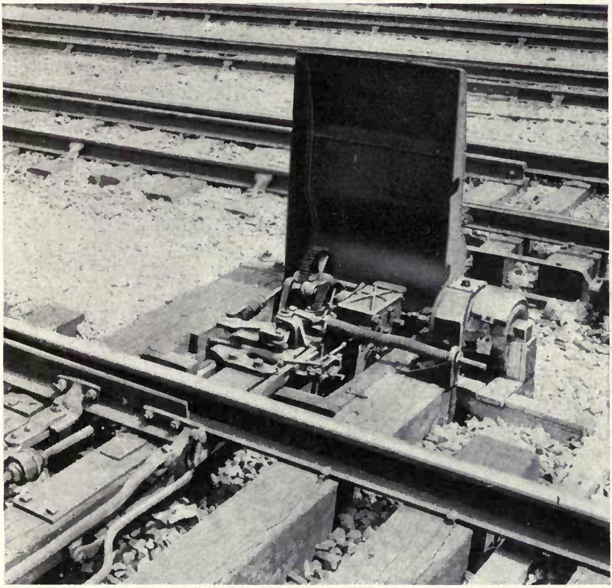


FIG. 41. MODEL 2 SWITCH MACHINE. CLINTON STREET INTERLOCKING PLANT, CHICAGO TERMINAL, C. & N. W. R'Y

Spring attachment shown is furnished with Model 2 switch machine when detector bar is not installed.

control of the pole changer prevents the switch from being moved by hand from the position occupied, except through breaking the operating circuits by some such means as removing the motor brushes. If this is done and the machine moved to a position not corresponding with that of its controlling lever, upon the replacement of the brushes, the switch will immediately assume its proper position. Manipulation of the pole changer by hand will not cause movement of the switch out of correspondence with its lever.

Model 2 Switch Machine

The Model 2 switch machine, illustrated by Fig. 43, consists of the motor, gearing, lock movement and the pole changer with its actuating movement. The gear frame and locking movement are securely bolted to a tie plate as shown, to which plate the stock rails are also securely attached, thus rigidly maintaining all parts of the switch machine in their proper relation to each other and to the rail.

Movement is transmitted to the various switch parts by the motor through a train of spur gears.

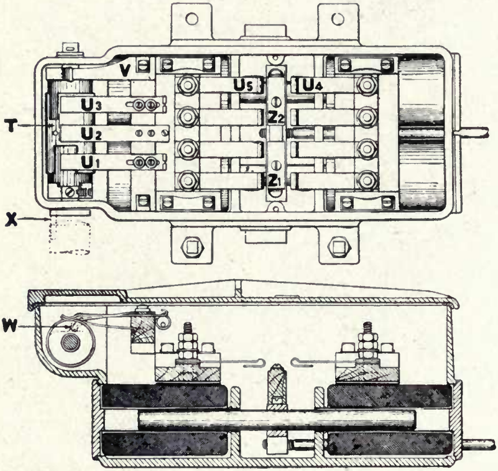


Fig. 42. Pole Changer for Model 2 Switch Machine

The locking plunger I and detector bar are actuated through the lock crank H and the driving rod G, this latter being directly connected to the stud F on the main gear D_1. It will be seen that a train occupying the track, in preventing the initial movement of the detector bar, would make impossible the withdrawal of the lock plunger from the throw and lock rods, and therefore prevent any movement of the switch points.

The switch points are thrown by the rod J and the cam crank E due to the stud F on the main gear engaging with the cam crank.

The operation of the pole changer B is effected through the medium of the pole changer movement L by the last one-eighth inch movement of the lock plunger I after it has passed through the lock rod K (Fig. 146).

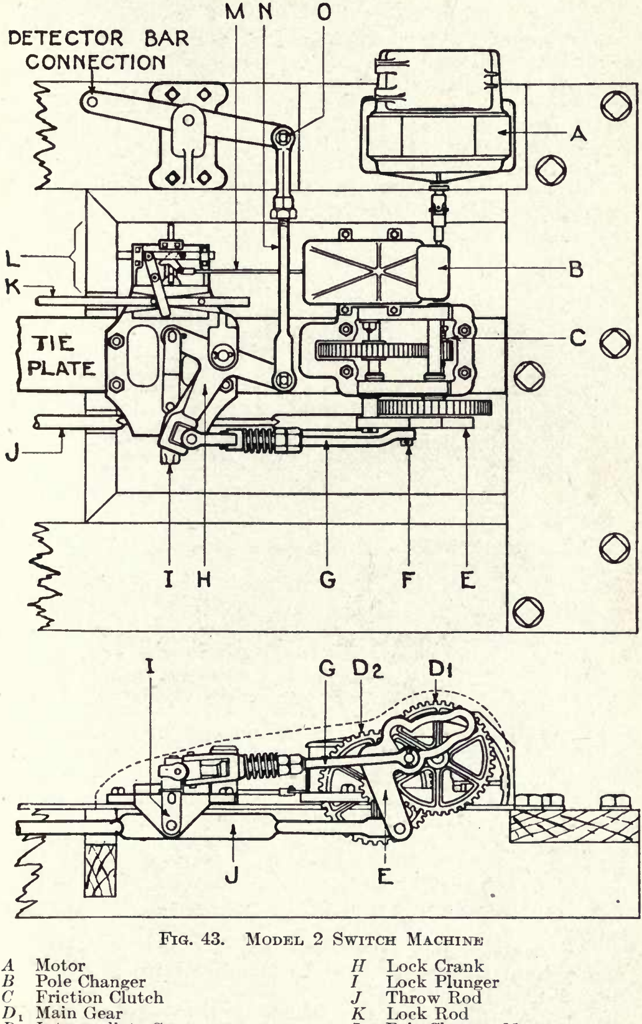


FIG. 43. MODEL 2 SWITCH MACHINE

A	Motor	*H*	Lock Crank
B	Pole Changer	*I*	Lock Plunger
C	Friction Clutch	*J*	Throw Rod
D_1	Main Gear	*K*	Lock Rod
D_2	Intermediate Gear	*L*	Pole Changer Movement
E	Cam Crank	*M*	Pole Changer Connecting Rod
F	Stud on Main Gear	*N*	Detector Bar Driving Link
G	Driving Rod	*O*	Pin

- *A* Motor
- *B* Intermediate Gear
- *C* Friction Clutch
- *D* Main or Cam Gear
- *E* Roller on Main Gear
- F_1, F_2 Locking Bars
- G_1, G_2 Rollers on Locking Bar
- H_1, H_2, H_3 Locking Dogs
- I_1, I_2 Lock Rods
- *J* Throw Rod
- *K* Jaw in Throw Rod
- *L* Locking Bolt
- *M* Pole Changer
- *N* Tripper Arm
- *O* Switch Circuit Controller Location
- *P* Pin
- *S* Detector Bar Connection

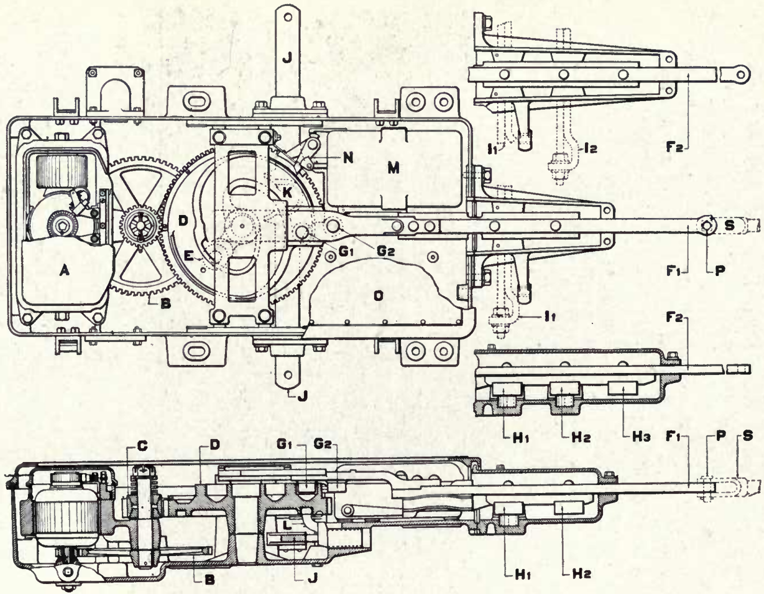


Fig. 44. Model 4 Switch Machine
Showing single and double locking cages.

The design of the mechanism is such as to allow the switch motor A, due to its acquired momentum, to continue its rotation for the generation of the indication, which checks the speed of the motor and brings it to rest without shock.

A friction clutch C is introduced into the connection between the switch motor and the main gear to relieve the switch mechanism from any injurious strain should it suddenly be brought to stop by an obstruction in the switch points.

Model 4 Switch Machine

The Model 4 switch machine shown in Fig. 44, is designed with all operating parts within one case, and is especially adapted for installation where clearances are limited. The

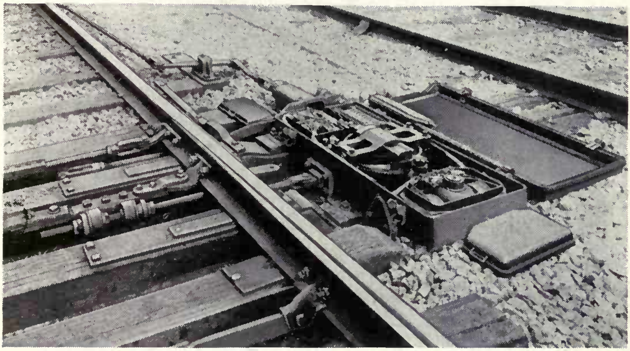


Fig. 45. Model 4 Switch Machine. Noble Street Interlocking Plant, Chicago Terminal, C. & N. W. R'y

case, which affords complete protection against the weather, provides a base plate for the mechanism, being bolted through the tie plate to the head block and the next tie back (Fig. 149). The operating parts consist of the motor A, a train of spur gears, the main or cam gear D, the pole changer M, the throw rod J and locking bar F.

The motor through the medium of the train of gears drives the cam gear, from which gear the various parts of the switch machine are operated.

The intermittent movement of the locking bar and detector bar is accomplished by the engagement of rollers on the locking bar with the cam slot on the upper side of the main gear. Staggered locking is provided by the arrangement of the dogs on the locking bar, these dogs being placed so that after one dog has been withdrawn to release the lock rod, the switch points must be moved to the opposite position before the other dog can enter its slot in the lock rod. The throw rod is locked in both extreme positions of the switch by a bolt operated from the cam movement.

The switch points are thrown at the proper time by a roller on the lower side of the main gear engaging a jaw in the throw rod.

The principles of the pole changer movement are essentially the same as in the Model 2 switch machine, although the mechanical method of effecting this action is accomplished through the main gear movement and locking bar, instead of

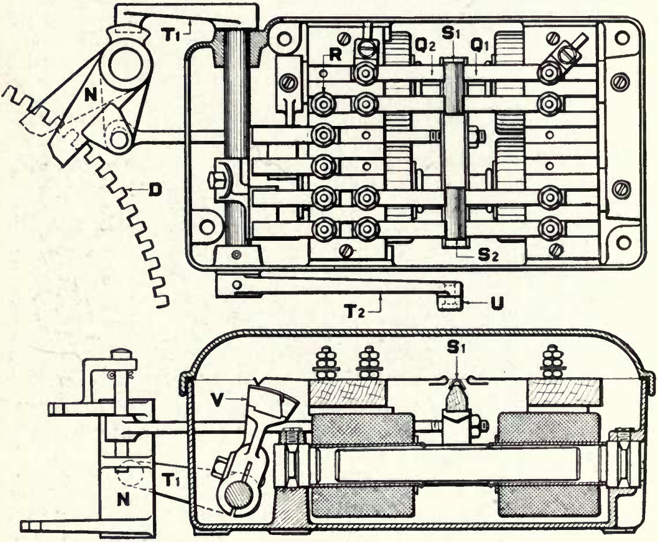


FIG. 46. POLE CHANGER FOR MODEL 4 SWITCH MACHINE
Tripper arm N shown at the top of its vertical movement.

through the pole changer movement and locking plunger as in the Model 2. Contact blocks S_1 and S_2 are operated from tripper arm N which engages at the proper time with a cam either on the upper or lower surface of the main gear D, depending on the direction of travel of the mechanism. The tripper arm is placed in a position to engage with the proper cam only after the switch has been locked in position at the end of its movement. This is accomplished through the medium of cranks T_1 and T_2, a roller U on the latter working in a cam slot on the locking rod F_1. The contact arm V (which corresponds with the commutator T on the Model 2 pole changer, Fig. 42) is operated by this same crank movement.

The cam gear is designed to permit a free run of the motor at the end of the operation of the mechanism for the purpose of generating a strong and positive indication current.

A friction clutch, designed with large surfaces and lined with fibre, is provided to protect the mechanism from shock, should its movements be obstructed.

A switch circuit controller can be furnished if desired, located within the mechanism case at the point indicated by letter O. The operating part consists of a frame carrying contact fingers and a cylindrical commutator W upon which are mounted contact segments. As the switch is unlocked, a disengaging arm X with roller Y working in a cam slot on the locking bar F_1, lowers the commutator out of engagement with the contact springs. During the movement of the switch points, the commutator is rotated on its axis through motion

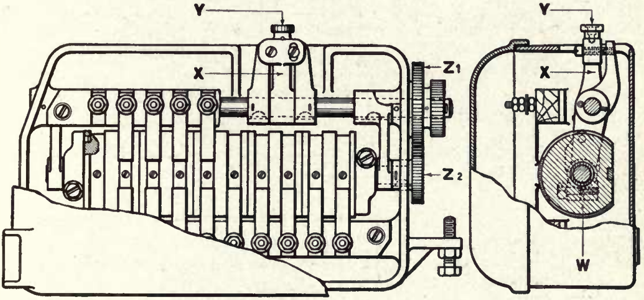


Fig. 47. Switch Circuit Controller for Model 4 Switch Machine

transmitted from the switch points by means of a crank connection, a sector (not shown) and pinions Z_1 and Z_2. After the points are locked in position the commutator is raised into engagement with the contact fingers by the engaging arm and cam slot movement. It will be seen that this control insures the switch points are in position and locked in position before the switch circuit controller can be closed. The maximum capacity of the controller is ten independent circuits, the contacts being adjustable in pairs to close as desired at the normal or reverse positions of the switch.

The switch mechanism can be used right or left handed without change, as the lock and throw rods may be connected from either side. A double locking cage is furnished when the machine is to operate a double slip switch or movable point frog, thus avoiding the necessity of using a plunger lock with its special connections otherwise required for the second lock rod.

All parts are assembled in the factory and tested before shipment under conditions approximating as nearly as possible the service to be given the machine after installation.

MOTOR DRIVEN SIGNAL MECHANISMS

MOTOR driven signals in the G. R. S. system of electric interlocking are operated by mechanisms in which a series wound motor is directly connected to the semaphore shaft through the medium of low reduction gearing. No dash-pot or electro-mechanical slot is required for this type of signal. The mechanism is applicable for use as a high or dwarf signal.

The mechanisms furnished are of two types:

First, the non-automatic, which is entirely under the control of a lever in the interlocking machine. Generally speaking, this type is furnished for dwarf signals, and for such high signals as will at no time require track circuit control.

Second, the semi-automatic, which is operated under the joint control of a lever in the interlocking machine and the track circuits in such sections of track as are governed by the signal arm. The semi-automatic mechanism is also furnished for non-automatic high signals when there is a possibility of the signal arm being controlled by track circuits at some future time, or in case it is desired to have uniformity in the type of mechanism throughout the installation.

Either of the above types can be adapted for operation in two or three positions, upper or lower quadrant, and to give right or left hand indications as desired.

In the two position non-automatic signals, but one wire besides the main common is required for its control, this wire being used both for operating and indicating purposes. When the signal is to operate in three positions an additional control wire is required. In the case of semi-automatic control, an additional wire may or may not be required, depending entirely upon the arrangement of the track circuits in the route governed by the signal arm.

NON-AUTOMATIC SIGNAL CONTROL

The following description of the signal operation is based on the circuit shown in Fig. 48 which is for the control of the two position non-automatic signal mechanism.

Upon reversal of the controlling lever current is taken from the positive buss bar through the lever contacts, the control wire, the operating field and armature of the signal motor, and thence to common through the various switch circuit controllers as required. This causes the movement of the blade from stop to the proceed position, upon the completion of which movement circuit breaker contact B opens and A closes, this connecting the holding field of the motor in series with the operating field and armature. The design of the pole pieces on which the holding field windings are mounted, is such that the magnetic flux, thrown across the air gap between the motor armature and the pole pieces, magnetically locks the armature against rotation and thereby retains the

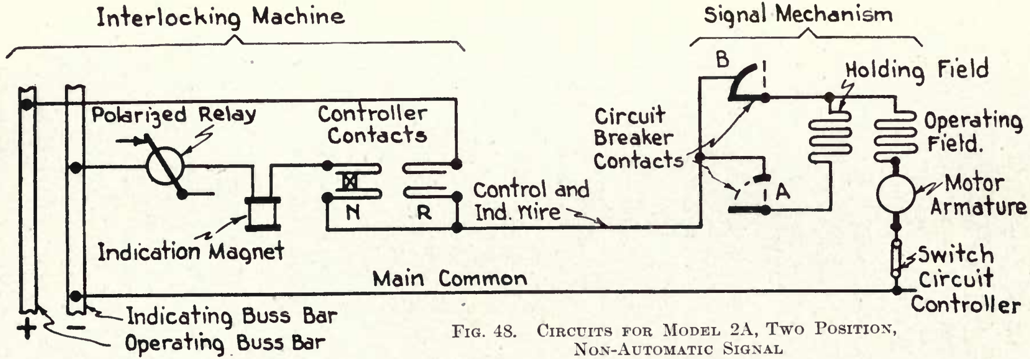


FIG. 48. CIRCUITS FOR MODEL 2A, TWO POSITION, NON-AUTOMATIC SIGNAL

signal arm in the desired position so long as the circuit is intact. Since the holding field windings have a high resistance the current used to hold the signal in the proceed position is reduced to a minimum.

The signal lever is not indicated in the reverse position, since no safety features are sacrificed, should the signal fail to assume the proceed position upon the reversal of its controlling lever.

When the lever is placed in its normal indication position, energy is cut off from the motor and the signal arm returns by gravity to the stop position, this causing the gearing and motor armature to revolve backwards to their original position. Contact A opens at the beginning of the movement and contact B closes just before the signal arm reaches the stop position, this connecting the motor armature and operating field in their original closed circuit in which is included the indication magnet. Due to the acquired momentum of its armature, the motor (now a generator) produces a dynamic current in this circuit, which effects the release of the controlling lever and permits it to be restored to the full normal position. The generation of the indication current effectually checks the speed of the returning mechanism and brings it to rest without shock to any of its parts.

In the case of the three position signal, operation from the zero degree position to the forty-five degree position is the same as described above. Operation from this point on to the ninety degree position is ordinarily dependent upon the signal in advance, it being necessary however that the controlling lever be reversed before movement of the mechanism can take place. The mechanism is held in its ninety degree position through the medium of the holding fields in the same manner as in the forty-five degree position. When the signal arm is returning from the ninety degree position and is to be held at the forty-five degree position, its movement is arrested at that point by short circuiting a " snubbing " winding on the motor (winding and contact not shown in Fig. 48), which causes a momentary current to flow in this winding, thereby bringing the mechanism parts to rest. The semaphore arm is retained in this position by current flowing through the retaining fields of the motor, as previously explained.

Semi-Automatic Signal Control

When it is desired to have the signal controlled semi-automatically, the operation differs from that described above in that the first forty degree movement of the mechanism from the normal position does not affect the position of the signal arm, but puts under tension a set of coil springs which are strong enough to rotate the motor on the return movement with sufficient speed to generate the current for energizing the indication magnet on the lever. This preliminary movement of the mechanism is always under the control of the operating lever irrespective of whether the track circuit is occupied or not, the receipt of the indication therefore not requiring the restoration of the lever to the normal position simultaneous with the entrance of a train into the controlling track section. Any movement of the mechanism beyond this point, however, is dependent upon the track circuit being unoccupied.

Referring to the circuit for the two position semi-automatic signal as shown in Fig. 49, it will be seen that upon reversal of the controlling lever current is taken from the positive buss bar through the lever contacts, the control wire, the signal motor operating field and armature and thence to common. This causes the operation of the mechanism through its preliminary forty degree movement to the zero degree position, at which point the mechanism will be held against the tension of the coil springs, in the event of the track circuit being occupied; this is accomplished by circuit breaker contact B_1 opening and A_1 closing which connects the holding fields in series with the operating fields and armature of the signal motor. Should the track circuit be unoccupied, the mechanism will not stop at this point but

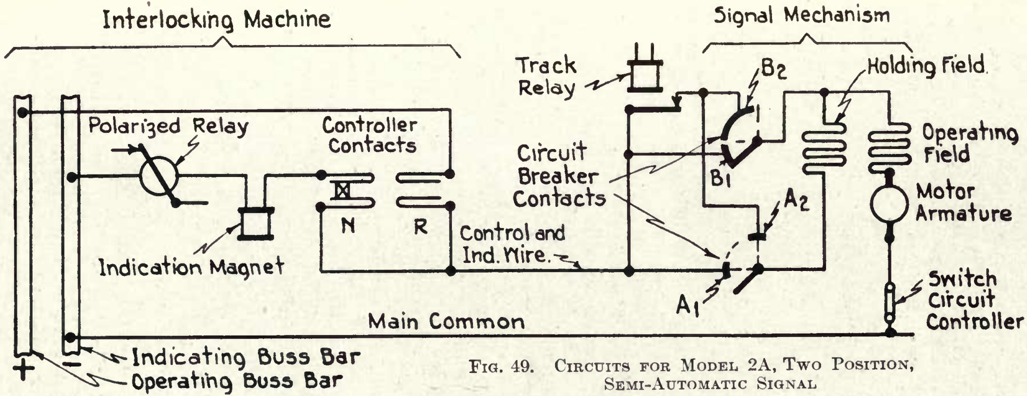


FIG. 49. CIRCUITS FOR MODEL 2A, TWO POSITION, SEMI-AUTOMATIC SIGNAL

will continue its movement, current being taken through the track relay contact and circuit breaker contact B_2; the movement of the mechanism from the zero degree position on, carries the semaphore blade with it to the proceed position. Just before reaching this position circuit breaker contact B_2 opens, and A_2 closes, again cutting the holding field in series with the operating field and armature, thereby retaining the signal mechanism and signal arm in the proceed position.

Upon the entrance of a train into the track section controlling the signal, the opening of the track relay cuts current off from the motor which causes the signal arm and mechanism to return to the zero degree position. The speed of the returning mechanism is checked at this point by "snubbing" the motor in the same manner as at the forty-five degree position of the non-automatic mechanism. Circuit breaker contact A_1 closes, thereby retaining the mechanism in the zero degree position during such time as its lever may be reversed; the control is so arranged that a second clearing of the signal arm can be secured only after the mechanism has been returned to its minus forty (−40) degree position. When the lever is restored normal, energy is cut off from the motor and the mechanism, due to the tension of the coil springs, is driven to its minus forty (−40) degree position; just before reaching this position circuit breaker

Fig. 50. Model 2A Dwarf Signal. Electric Division, N. Y. C. & H. R. R. R.

contact B_1 closes, thus connecting the motor armature and operating field in their original closed circuit in which is included the indication magnet. Due to the momentum of the motor armature acquired during this movement, the motor (now a generator) builds up the momentary dynamic current necessary to energize the indication magnet and release the lever, thereby permitting it to be restored to its full normal position.

Should the controlling lever be placed normal before the entrance of a train into the controlling track section, the signal arm and mechanism returns to the zero degree or stop position, and the mechanism continues its rotation to the minus forty (−40) degree position due to the action of the indication springs; when within a few degrees of the end of its travel, the dynamic indication for the release of the controlling lever is generated as described above.

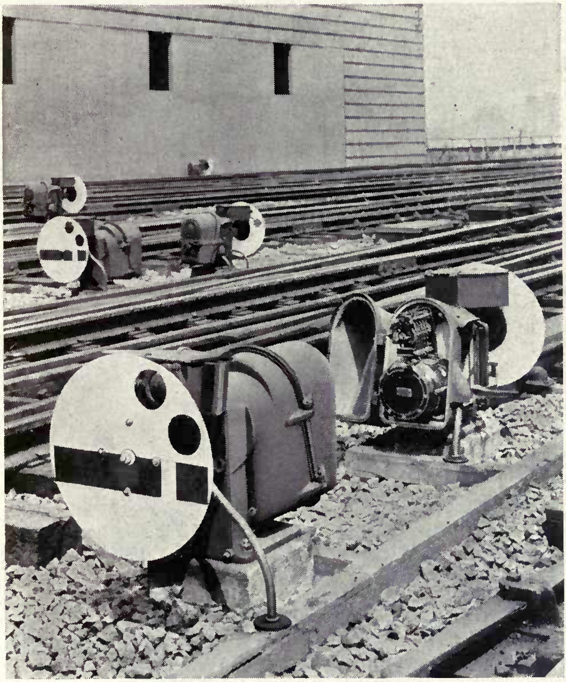


FIG. 51. MODEL 2A DWARF SIGNALS. CHICAGO TERMINAL, C. & N. W. R'Y

It will be seen that the operation of the signal mechanism proper, from the time the signal blade begins its movement toward the proceed position until its return to the stop position, is the same as that of the non-automatic signal, the indication springs being in no way depended upon to bring the signal arm to the stop position. This same statement applies also to three position operation of the semi-automatic mechanism.

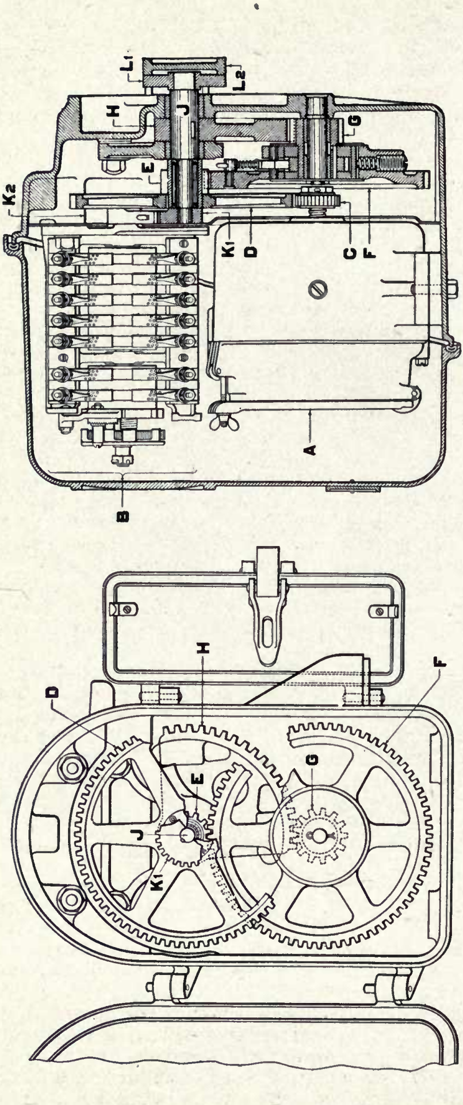


FIG. 52. MODEL 2A NON-AUTOMATIC SIGNAL MECHANISM

A	Motor	*G*	Second Intermediate Pinion
B	Circuit Breaker	*H*	Operating Sector
C	Driving Pinion	*J*	Driving Shaft
D	First Intermediate Gear	K_1–K_2	Segmental Gears
E	First Intermediate Pinion	L_1–L_2	Universal Coupling
F	Second Intermediate Gear		

Model 2A Non-Automatic Signal Mechanism

The non-automatic signal mechanism (Fig. 52) consists essentially of three main parts, the motor, a train of gears and the circuit breaker. These are all housed in a weather proof case, which is provided with doors to give convenient access to all parts.

When the mechanism is used for the operation of high signals, it is fastened to a clamp bearing (Fig. 54) which carries the semaphore shaft S, the design of this bearing permitting the mechanism to be supported at any desired height on the signal mast and at any angle to the track. The bearing is equipped with a spring stop P, which besides acting as a buffer permits the close adjustment of the signal blade in its stop position. A universal coupling L_1, L_2, L_3 introduced between the driving shaft J and semaphore shaft S, lends itself to a simple means of locking the signal arm in the stop position in such a way as to prevent improper operation of the signal by any outside agency.

When the signal mechanism is to be used for the operation of a dwarf signal, it is bolted to a stand (Fig. 55) carrying the spectacle shaft T and provided with springs U_1 and U_2 which are for the purpose of giving sufficient returning torque to the dwarf signal arm to cause it to assume the stop position when the current holding it at proceed is cut off. This is necessary since the dwarf signal arm cannot be readily designed to have sufficient weight so that gravity can be depended upon for returning it to the stop position. The complete dwarf mechanism takes up but little room which permits it to be installed where clearances are limited, as is illustrated by Fig. 202.

The motor A used in the signal mechanism is of the four pole type, two of these poles being modified in such a manner as to permit the motor armature to constitute the means for holding the signal arm in the proceed positions. This modified design consists of serrating the surfaces of these two poles, so that when the holding field windings are energized, a dense magnetic flux will flow across the air gap between the pole pieces and the motor armature in such a manner as to prevent rotation of the armature, and, consequently, movement of the signal blade. Owing to the high resistance of these windings the amount of current used for the purpose is reduced to a minimum. The "snubbing" winding previously referred to is entirely independent from the operating windings of the motor, its function being to check the speed of the motor when it is desired to hold the signal arm in the forty-five degree position.

A friction clutch is introduced between the motor A and its driving pinion C to insure that no undue strain whatsoever will be transmitted to the mechanism gearing.

The gearing is designed with heavy teeth and large clearances as shown by Fig. 53, this latter insuring that the mechanisms will run freely in either direction and that no ordinary obstructions such as dirt, cinders, waste, etc., will interfere with its movement; only five foot pounds at the semaphore shaft are required to run the mechanism back to its normal position.

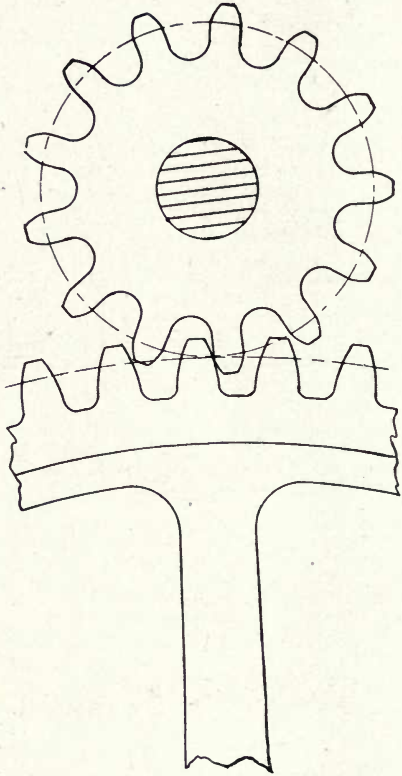


Fig. 53. Diagram Illustrating Gearing Clearance in Model 2A Signal Mechanism
Scale, full size.

The circuit breaker B is a complete unit operated from the main driving shaft J by means of the segmental gears K_1 and K_2. It consists of a frame carrying contact fingers and a revolving commutator on which are mounted contact segments as required. The circuit breaker has a maximum capacity of fourteen circuits, such contacts as are used to control operating and indicating circuits being arranged to be quick acting, "snapping" over from one position to the other at the proper predetermined time. Each contact finger is provided with convenient means of adjustment, and by means of a locking finger is positively protected again accidental displacement.

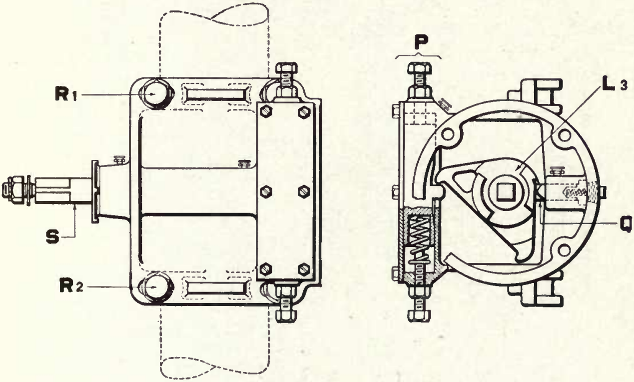


Fig. 54. Clamp Bearing for Mounting Model 2A Signal Mechanism on Signal Mast

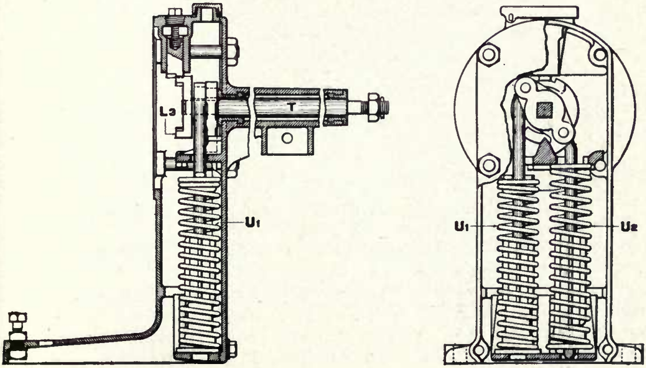


Fig. 55. Dwarf Bearing for Model 2A Signal Mechanism

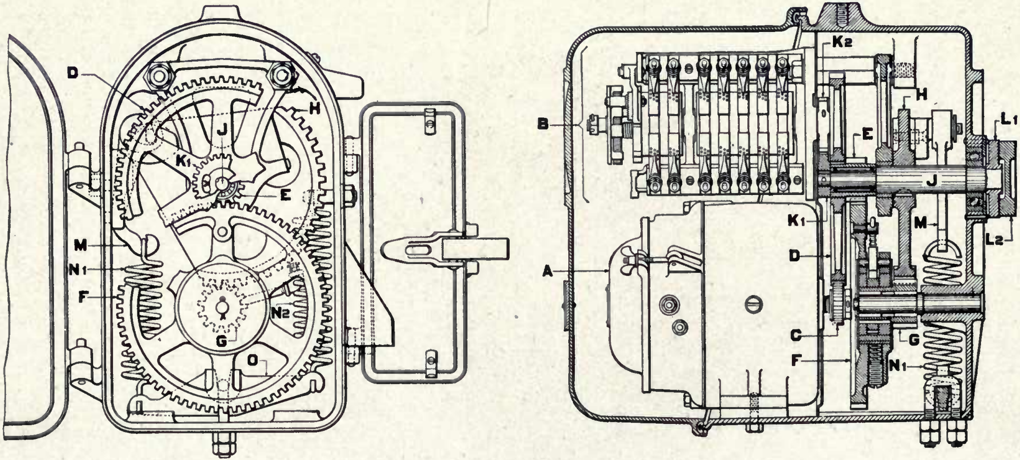


FIG. 56. MODEL 2A SEMI-AUTOMATIC SIGNAL MECHANISM

A	Motor	*H*	Operating Sector
B	Circuit Breaker	*J*	Driving Shaft
C	Driving Pinion	K_1–K_2	Segmental Gears
D	First Intermediate Gear	L_1–L_2	Universal Coupling
E	First Intermediate Pinion	*M*	Hook
F	Second Intermediate Gear	N_1–N_2	Coil Springs
G	Second Intermediate Pinion	*O*	Equalizer

Model 2A Semi-Automatic Signal Mechanism

The semi-automatic signal mechanism (Fig. 56) consists essentially, as does the non-automatic mechanism, of a motor, a train of gears and circuit breaker, with the addition, however, of the spring attachment which is used to produce rotation of the motor armature for indication purposes after the signal arm has reached the stop position. These parts are enclosed in a weather proof case similar in construction to that used for

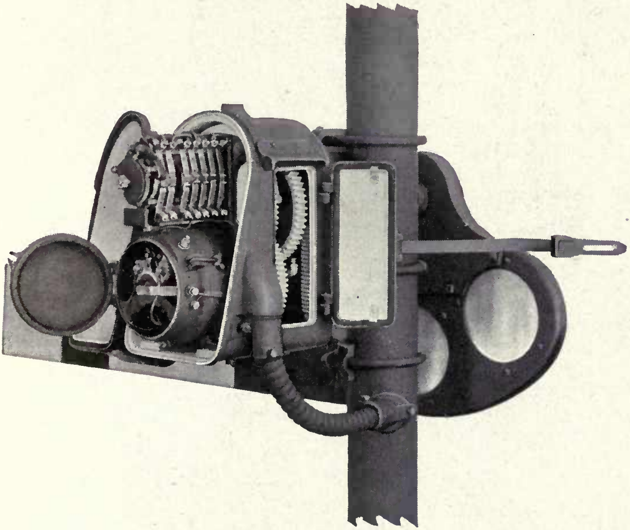


Fig. 57. Model 2A Semi-Automatic Signal

the non-automatic signal, the design permitting the mechanism to be fastened to a clamp bearing for mounting on high signal masts or used in connection with a stand for operation as a dwarf.

The motor, train of gears and circuit breaker are essentially the same as those described above, it being therefore only necessary to touch upon the design of the indication spring attachment and the universal coupling, these being the only points in which this signal is radically different from the non-automatic previously described.

The initial free movement of the mechanism is accomplished by having one shoulder of the coupling L_2 so cut away that a forty degree rotation of the driving shaft J is necessary before it will engage with the semaphore shaft S, this movement as previously mentioned putting under tension the pair of coil springs N_1 and N_2.

Fig. 58 shows diagramatically this spring attachment and the manner in which the springs N_1 and N_2 are put under tension; it will be noted that the two coil springs are connected to the driving shaft J by means of an equalizer O and a curved link

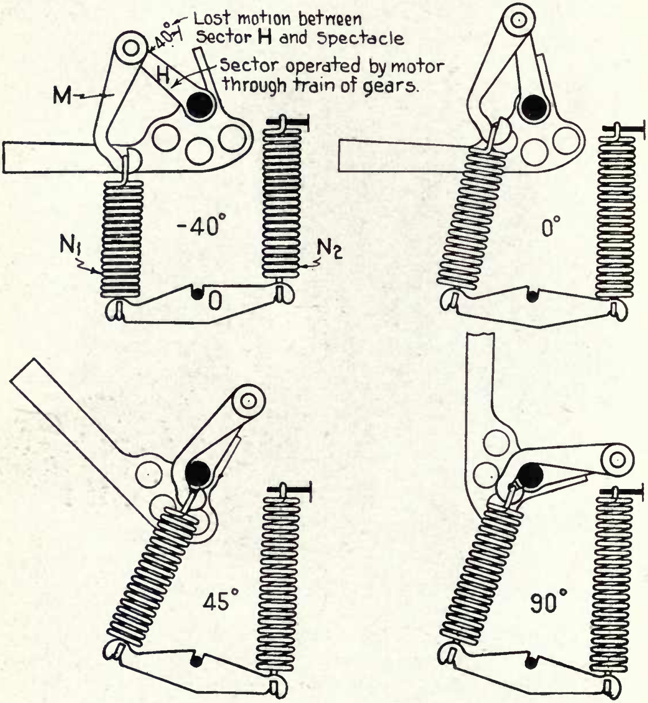


FIG. 58. DIAGRAM SHOWING OPERATION OF SPRING ATTACHMENT USED IN MODEL 2A SEMI-AUTOMATIC SIGNAL MECHANISM

M, one end of which is fastened to the main sector H on the driving shaft J. As is clearly illustrated by the various positions of the device the design is such that the springs do not exert any torque on the mechanism after the blade has moved a few degrees from the stop position; therefore it is plain that the springs are in no way depended upon for the restoration of the blade to the normal position.

SOLENOID DWARF SIGNAL MECHANISMS

SOLENOID dwarf signals used in the G. R. S. system are designed to operate in two positions, upper or lower quadrant, with a forty-five, sixty or ninety degree travel of the arm. Two sets of magnet windings are provided, which consist of operating coils of low resistance and holding coils of high resistance. The movement of the solenoid magnet plungers is transmitted by means of suitable connection to the dwarf spectacle.

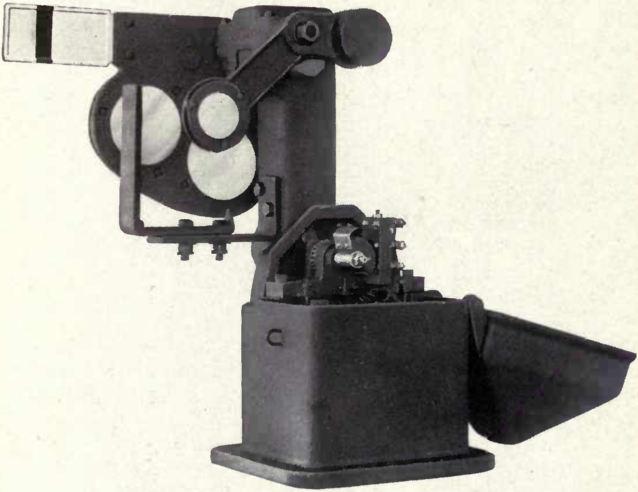


FIG. 59. MODEL 2 SOLENOID DWARF SIGNAL

DWARF SIGNAL CONTROL

Each of these mechanisms requires for its operation a control wire, and since it is impracticable to secure a dynamic indication from a signal of the solenoid type, an additional wire is required for indication purposes. The circuit is connected to main common either at the dwarf location or through contacts on switch circuit controllers when required.

Upon reversal of the controlling lever (Fig. 60), current is taken from the positive buss bar through the lever contacts, the control wire, and the solenoid operating coils A_1 and A_2 to common. This causes movement of the signal arm from the stop to the proceed position. As the arm reaches the proceed position, the circuit breaker contact C opens, which connects the high resistance holding coils B_1 and B_2 in series

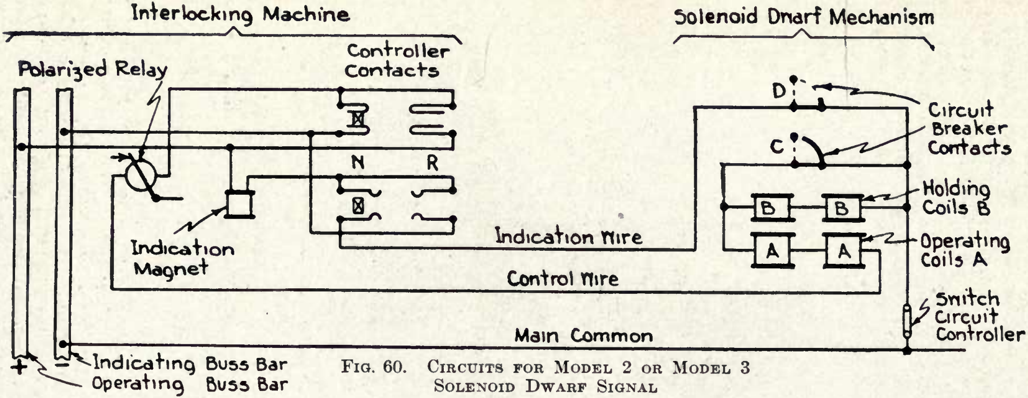


Fig. 60. Circuits for Model 2 or Model 3 Solenoid Dwarf Signal

with the operating coils, the flow of current being thereby reduced to the minimum required to retain the arm at proceed. The full movement of the lever to the reverse position is accomplished by means of a local battery indication.

When the signal lever is placed at its normal indicating position, all energy is cut off the coils and the signal arm returns to the stop position. As the arm reaches this position, contact D is closed, this permitting the indicating magnet to be energized by current taken from the main battery, which effects the release of the controlling lever and allows its normal movement to be completed. It will be noted that as soon as the lever is moved past the indicating point, the indication circuit is opened at the lever, to prevent unnecessary waste of current.

Model 2 Dwarf Signal Mechanism

The Model 2 dwarf signal mechanism (Fig. 61), which consists of the solenoid magnets, a rack and pinion movement and crank, is mounted in a case which, in addition to supporting the mechanism, is designed to carry the dwarf spectacle shaft. A hinged cover on the top of the case gives convenient access to the mechanism.

The movement of the yoke F connecting the solenoid plungers E_1 and E_2, is transmitted through the medium of the rack G and pinion H to the crank J, and thence by means of the connecting rod (not shown) to the dwarf spectacle shaft.

When in the stop position the signal arm cannot be moved by any outside agency, due to the crank J being "on center" at that point.

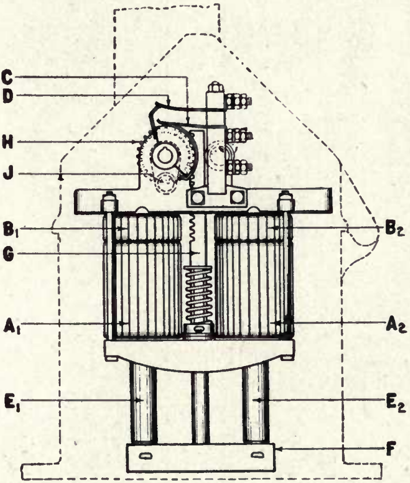


Fig. 61. Model 2 Solenoid Dwarf Signal Operating Mechanism

A_1–A_2	Operating Coils	F	Yoke
B_1–B_2	Holding Coils	G	Rack
C	Operating Contact	H	Pinion
D	Indicating Contact	J	Crank
E_1–E_2	Solenoid Plungers		

The circuits for the control of the mechanism are broken through pairs of springs which make contact at the proper time with metal pieces, fastened to a commutator mounted upon the same shaft as the pinion H. The operating contact C is designed to hold its circuit closed throughout the movement until the blade has assumed the proceed position. The indicating contact D is closed only when the blade is in the stop position.

Model 3 Dwarf Signal Mechanism

The Model 3 dwarf signal mechanism (Fig. 63) consists of the solenoid magnets and an operating rod which is directly connected to the dwarf spectacle shaft. This mechanism is mounted in a case which is designed to carry the dwarf spectacle shaft and is provided with a sliding cover to permit ready access to the operating parts.

The operation of the mechanism is similar in principle to that of the Model 2 dwarf except that the movement of the

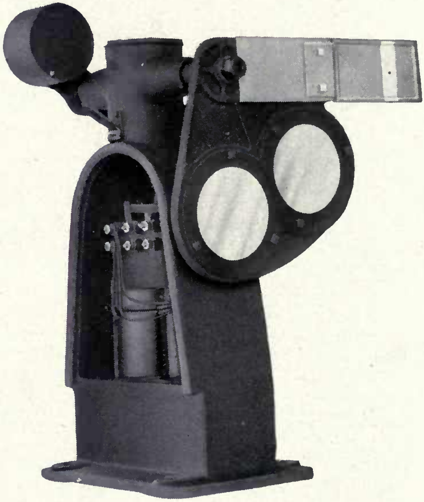


Fig. 62. Model 3 Solenoid Dwarf Signal

magnet plungers E_1 and E_2 is transmitted directly to the spectacle shaft through the operating rod G, a roller H on the operating rod working in an escapement crank (not shown) on the semaphore shaft. The design is such that when the signal is in its normal position, the arm is locked against movement from the outside.

The overall dimensions of the signal are such as to allow its location where the available clearances will not permit the use of the Model 2 dwarf signal.

The circuit breaker contacts consist of pairs of springs which are bridged by contact rollers, actuated by the operating rod G. In the case of the indicating contact D and spare contact J, the contact rollers are fastened to and move with the operating rod, the design causing the contacts

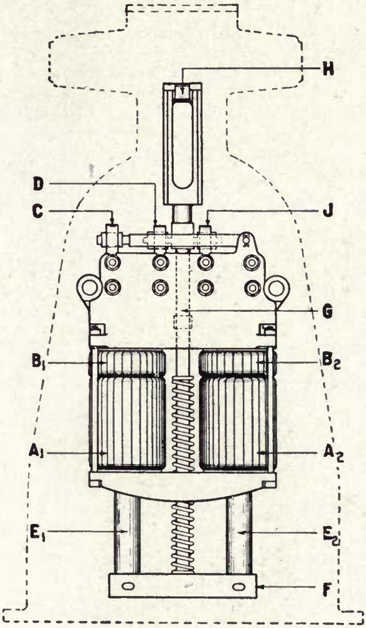


FIG. 63. MODEL 3 SOLENOID DWARF SIGNAL OPERATING MECHANISM

A_1–A_2	Operating Coils	F	Yoke
B_1–B_2	Holding Coils	G	Operating Rod
C	Operating Contact	H	Roller
D	Indicating Contact	J	Spare Contact
E_1–E_2	Solenoid Plungers		

to open with the first movement of the arm towards the proceed position. The roller for the operating contact C is carried by an arm, which is raised by engagement with a collar on the operating rod, when the dwarf spectacle has assumed the proceed position.

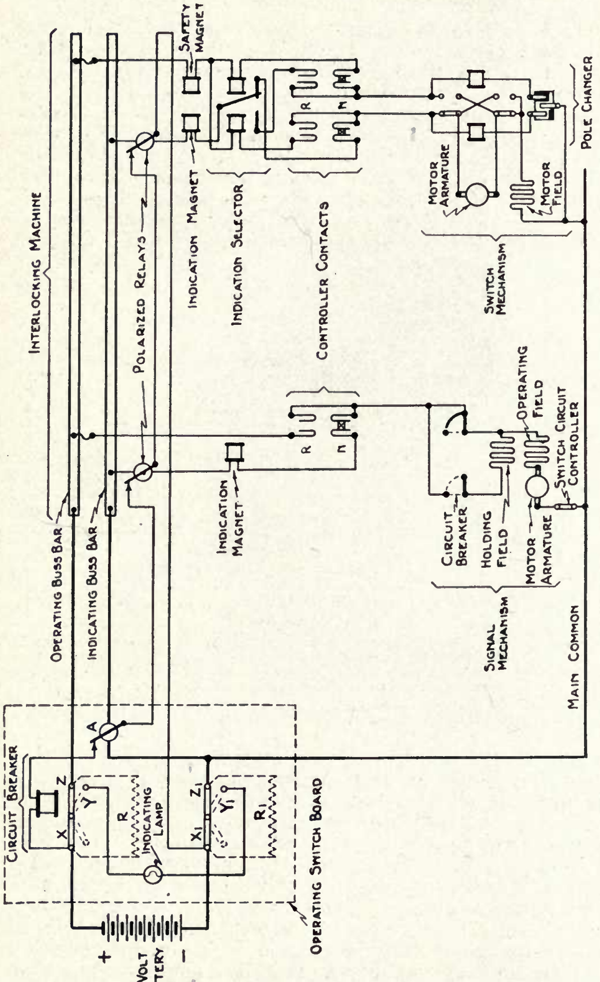


Fig. 64. Circuits for Operating Switchboard, Interlocking Machine and Switch and Signal Functions

CROSS PROTECTION APPARATUS

Principles of G. R. S. Cross Protection

THE G. R. S. cross protection system prevents the unauthorized movement of any switch, signal, or other function, in the event of current being improperly applied to its circuit, by the cutting off all energy from the function.

As briefly outlined in the pages on the "G. R. S. Electric Interlocking System," it has been seen that all functions while at rest are normally on a closed circuit of low resistance; that inserted in each of these circuits and located on the terminal board of the interlocking machine, is a polarized relay of very low resistance connected in such a manner that all currents, caused to flow through the circuit by the manipu-

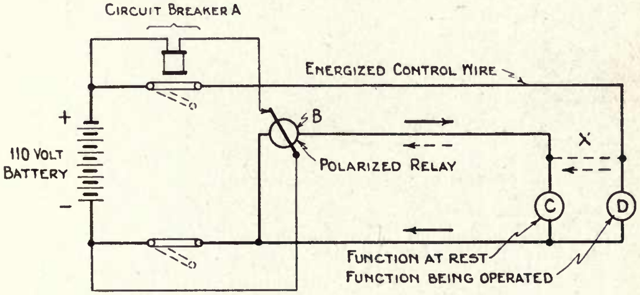


Fig. 65. Simplified Circuit Showing the Principles of the G. R. S. Cross Protection System

All functions when at rest are on closed circuit as shown by function C. All normal currents will flow through the polarized relay B in the direction indicated by the heavy arrows, but all currents due to a cross in the opposite direction as indicated by the dotted arrows. Hence current supplied through a cross X will open polarized relay B, which will cause circuit breaker A to open and thus cut current off the system.

lation of the lever, must pass through the relay in a direction to maintain its contact closed, while all currents which may be applied through any other channel must pass through this relay in a direction to cause it to open its contact; and that this operation breaks the control circuit of the cross protection circuit breaker, causing it to open and cut power off that section of the system affected, thereby preventing the unauthorized movement of the function. The principles involved will be made evident by reference to Fig. 65, from which circuit has been eliminated all detail connections, contacts, etc., only such parts being shown as are essential to the explanation.

In Fig. 64 there is shown in full circuit detail all apparatus and contacts pertaining to a switch function, a signal function,

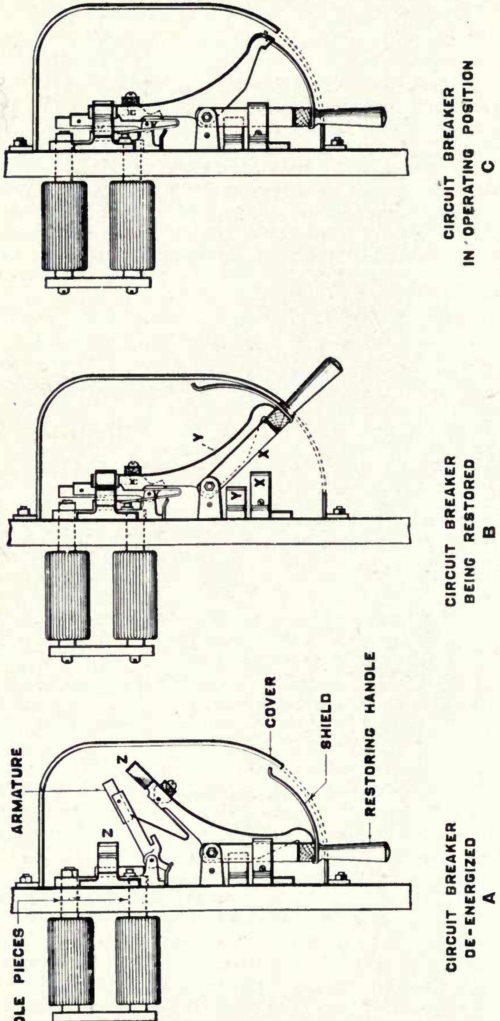


Fig. 66. Sectional View of Cross Protection Circuit Breaker
Parts similarly lettered make contact with each other.

and the system of cross protection. By tracing out these circuits it will be found that the circuit conditions as shown in Fig. 65 exist and afford the protection claimed.

Operation of the Cross Protection Circuit Breaker

The circuit breaker construction and its manipulation are clearly illustrated by Fig. 66, the position in Fig. 66C corresponding with that of the circuit breaker in Fig. 64. The various parts of the circuit breaker which make contact with each other are indicated by similar letters.

It has been shown that current applied from an unauthorized source to the circuit of a function at rest, causes the polarized relay in that function's circuit to open its contact and interrupt the circuit through the retaining magnet of the cross protection circuit breaker. When this occurs the circuit breaker armature is released and the Z contacts are opened, the armature falling to such a position (Fig. 66A) that it cannot be drawn up against the pole pieces by the magnetic pull which will be exerted when the retaining magnet is again energized through the restoration of the polarized relay armature. To inform the leverman that the circuit breaker is open, a red lamp is lighted by the closing of the Y contacts.

With the circuit breaker open as in Fig. 66A, the positive and negative feeder wires between the battery and the interlocking system are opened at the Z contacts, therefore the cross can have no effect. The polarized relay which had its armature reversed will identify the function affected and, upon the cause of the trouble being removed, the armature of this polarized relay will remain in its normal position, when replaced by the operator. This will cause the retaining magnet of the cross protection circuit breaker to be energized, and, by raising the restoring handle to the position shown in Fig. 66B the circuit breaker armature is restored to its operating position where it will be retained by the circuit breaker magnet. This action closes the Z contacts, but at the same time opens the X contacts, through which contacts are also broken the positive and negative feeder wires, this preventing the application of current to all functions controlled by the circuit breaker until the restoring handle is returned to its normal position. The red light is extinguished when the circuit breaker armature is restored.

Figs. 24 and 25 illustrate a typical operating switchboard, one view showing the cross protection circuit breaker exposed and the other with its cover in place. It will be noted that the only portion of the circuit breaker which is accessible to the leverman is the restoring handle projecting from the slot at the bottom of the cover. A shield attached to this handle closes this slot when the handle is in the normal position, thereby protecting the internal parts against manipulation in any way except by means of the restoring handle. As explained above, so long as the handle is held in a position to interfere with the release of the contacts normally retained by the magnet (Fig. 66B), energy is withheld from all functions under the control of the circuit breaker. These features make the cross protection system fully effective at all times, even though force of circumstances may require its being temporarily under the charge of unskilled employees.

When it is desired to retain such signals in the proceed position as may be occupying that position when the circuit breaker opens, resistance units R and R_1 (shown dotted in Fig. 64) are connected so as to bridge the X and Z contacts, these units permitting the flow of an amount of current sufficient to hold a limited number of signals at proceed. Their resistance is so high, however, that the mechanism requiring the least

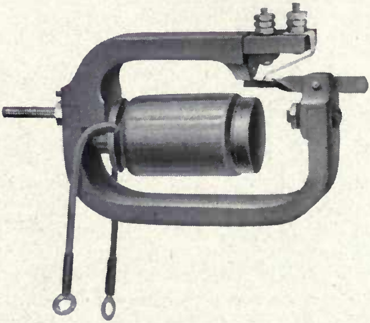


Fig. 67. Polarized Relay

current for its operation cannot be put in motion if energy should be applied to its circuit when the circuit breaker is open. The resistance units are shown in position on the operating switchboard in Fig. 24.

The Polarized Relays

The polarized relay inserted in the indication circuit of each of the operated functions, and mounted on the terminal board of the interlocking machine, is shown in Fig. 67. The windings are so designed that the armature of the relay for a switch, signal, etc., will reverse on about one-half the current required to just move that function of the same type which requires the least current for its operation. From this it will be seen that the windings of the polarized relays used with different types of functions have different resistances.

On the switchboard there is shown in Fig. 24 a polarized relay similar to those mounted on the interlocking machine, the position of this relay in the circuit (Fig. 64) being indicated by the letter "A." This relay guards against crosses between the buss bars on the interlocking machine, such as might be accidently caused by the maintainer's tools when he is working about the machine. From the position of the relay in the circuit, it will be seen that any current reaching the indication buss bar through such a cross will flow in the direction opposite to that of the indication currents, this causing the relay to reverse its contact in the same manner as the polarized relays previously described. Since the relay on the switchboard is common to all circuits, its winding is designed to render it much less sensitive than those on the interlocking machine.

Safeguards

To show that the system in addition to being extremely simple, is also fully safeguarded, the following points are mentioned:

First — The closed circuit principle is employed for all parts of the cross protection system.

Second — All contacts or connections depended upon for protection against crosses are also used in operation and, hence, are checked as to their integrity every time a complete operation of a function is made.

Third — The polarized relay contact, in addition to opening on a reversed direction of current, will also open upon loss of magnetism in the permanent magnet of the relay.

Fourth — An open circuit in the polarized relay prevents indication.

Sectionalizing of Plants

In connection with a comparatively simple track layout, it is common practice to install only one cross protection circuit breaker, which prevents the movement of all functions during such time as it may be open. At busy plants having a large number of routes which can be used simultaneously, it may be considered undesirable to have the whole plant affected by derangement at a single point, in which case the plant may be divided into sections, the functions in each section being controlled through separate circuit breakers. This permits uninterrupted operation of traffic through the sections not directly affected.

In addition to the cross protection circuit breakers required, it is necessary to install switchboard polarized relays and also common return wires for each section in the interlocking plant. The positive buss bar and indication buss bar must be divided to correspond with the sectional division of the functions. It is essential that there be no connections between the various buss bars or the common return wires, except where they join the energy mains from the battery, under the protection of their respective cross protection circuit breakers.

There may be certain situations where conditions will warrant the additional expense of employing individual cross protection circuit breakers for each switch and each group of signals. This would mean that a cross applied to a given switch, for example, would merely make that particular function inoperative without interfering with any of the other functions. The use of individual cross protection circuit breakers requires the running of a separate return wire for each of the functions or groups of functions concerned, and dispenses with the main common previously mentioned.

The device (Fig. 68) employed for this purpose consists of a modified form of the regular polarized relay, provided with suitable contacts and a restoring handle. The contact pressure is increased over that of the regular polarized relay, at the same time retaining the relay's sensitiveness to reverse currents, the contacts are heavier in design, and the iron in the magnet is so distributed that a powerful magnetic blowout is obtained which effectually extinguishes any arc resulting from currents flowing through the contacts at the time of their opening. The principles involved in the making and breaking of the circuits, and in the restoration of the relay armature to the operating position after having been reversed, are similar to those of the cross protection circuit breaker previously described. The device, as installed, is enclosed in a sealed case (Fig. 69) to prevent any improper manipulation of the circuit breaker parts.

This protective apparatus is mounted on the terminal board of the interlocking machine, occupying the same space as the regular polarized relay. The device, which is exceedingly simple in construction, is in no way subjected to weather conditions and is much more accessible than if located in the field at the various switches and signals, as is the ordinary practice with some systems employing individual cross protection.

Tests for Cross Protection

It has previously been stated that all contacts and connections depended upon for cross protection are under a constant automatic check during the regular operation of the different functions; therefore tests on the cross protection system are in no way requisite in the same sense that tests are necessary on switch points, to determine with what maximum opening the switch points can be locked. It is considered, however, that the satisfaction of having a working demonstration of the existence of the cross protection more than repays the slight trouble involved in making it one of the points to be checked up, on the regular inspection trip.

The time chosen for conducting such a test should be when the voltage on the system is at the highest point attained in service. This will be when the interlocking battery is being charged, at which time the current will run up above 140 volts.

The tests on the various switch functions may be secured by making a connection between the normal and reverse operating wires on the pole changer.

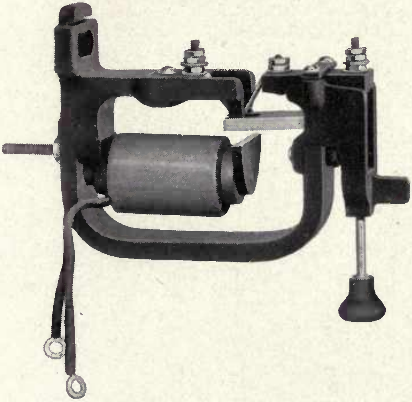


FIG. 68. INDIVIDUAL CROSS PROTECTION CIRCUIT BREAKER
Cover removed.

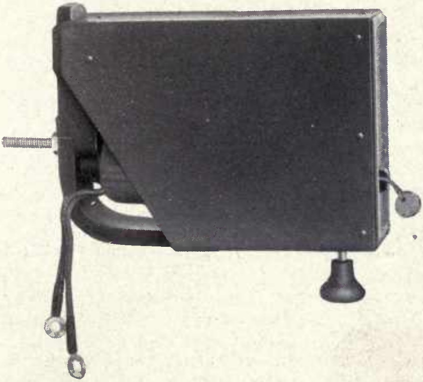


FIG. 69. INDIVIDUAL CROSS PROTECTION CIRCUIT BREAKER

In testing signals, the necessary energy may be obtained at the nearest switch mechanism, since one of the switch control wires is always connected to battery positive (Fig. 64). The test should be made by connecting energy onto the signal control wire as near as possible to the signal motor, and if the signal circuit is connected to the common return wire through one or more switch circuit controllers, the energy should be applied to this wire, care being taken to first open the connection to the main common wire. Failure to open this connection to common in all probability will result in blowing a fuse in the switch circuit from which the energy is being taken for the test, since under these conditions a short circuit to the common return wire is created.

Where the plant has been sectionalized, one or two functions in a given section should be crossed up with wires taking energy from each of the other sections. In case the functions in the various sections are widely separated, these crosses may be made between the binding posts in the terminal board of the interlocking machine, to avoid running a conductor long distances over ground. This test will insure that the proper division of the functions was made at the time of installation, and that no undesirable connections have since been made.

For the first test after an interlocking system has been installed it may be well to connect an adjustable resistance in the wires used in making the crosses, starting with the resistance all in and gradually cutting it down until the circuit breaker opens. For the periodical tests which some railway companies carry out this resistance is generally considered unnecessary.

ACCESSORIES

MODEL 3 FORM D SWITCH CIRCUIT CONTROLLERS

FIG. 70. MODEL 3 FORM D SWITCH CIRCUIT CONTROLLER
Two circuits, normal or reverse.

FIG. 71. MODEL 3 FORM D SWITCH CIRCUIT CONTROLLER
Two circuits normal and two reverse.

FIG. 72. MODEL 3 FORM D SWITCH CIRCUIT CONTROLLER
Four circuits normal and four reverse.

MODEL 5 FORM A SWITCH CIRCUIT CONTROLLER

The Model 5 Form A switch circuit controller arranged for selecting signal circuits is shown by Figs. 73, 74 and 75. The operation of the contacts, which are forced open and forced closed, is effected through a cam movement, which causes all wear to come on heavy iron parts and not on the contacts.

The contacts may be adjusted in pairs to make normal or reverse contact as required. One pair is adjusted by means of the screw jaw on the connecting rod and the other pair by means of the cam (Fig. 187), the parts after adjustment being positively locked against working loose. The contacts and binding posts are mounted on a vertical panel which gives convenient access to the binding posts when "connecting up" and permits ready inspection of the contacts.

Fig. 73. Model 5 Form A Switch Circuit Controller
Two circuits normal and two reverse, or four circuits normal, or four circuits reverse.

The case is provided with main and supplementary covers as shown by Fig. 74, the latter protecting the contacts from frost and condensation at all times, and when the main cover is open, from rain. The trunking cap and operating crank may be applied to either side of the circuit controller as proves most convenient in installation.

THREE POSITION D. C. MOTOR RELAY

The Three Position D. C. Motor relay is especially designed for wireless control automatic block signaling, but is readily adapted for use with three position polarized line circuits.

The operating mechanism consists of a small direct current motor having powerful permanent magnet fields with ample air gap between the armature and pole pieces. The contacts are moved from the de-energized position to either of the

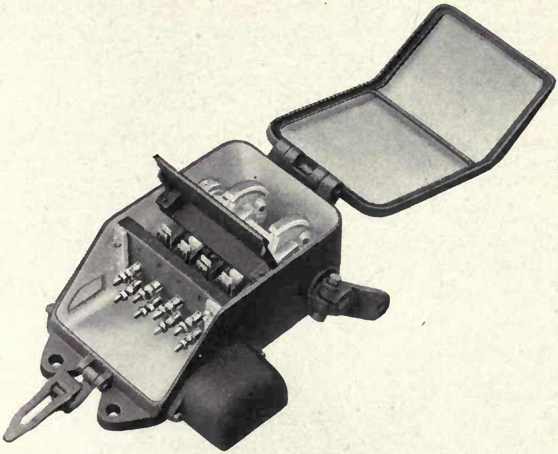


FIG. 74. MODEL 5 FORM A SWITCH CIRCUIT CONTROLLER FOR SELECTING SIGNAL CIRCUITS—MAIN AND SUPPLEMENTARY COVERS OPEN

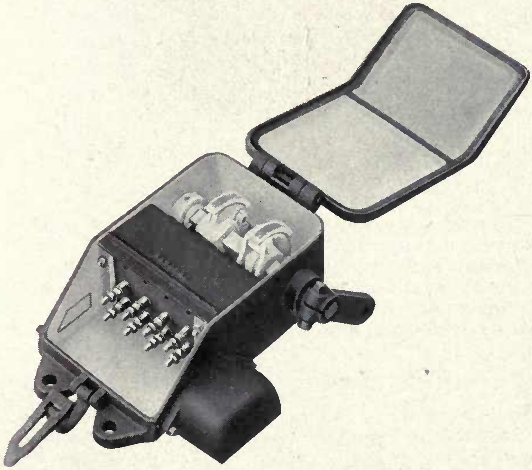


FIG. 75. MODEL 5 FORM A SWITCH CIRCUIT CONTROLLER FOR SELECTING SIGNAL CIRCUITS—MAIN COVER OPEN

Two circuits normal and two reverse, or four circuits normal, or four circuits reverse.

energized positions by the rotary motion of the motor armature, the movement of which is transmitted to the contacts by suitable link connections. The closing of one or the other sets of contacts is accomplished by a partial rotation of the armature, the direction being dependent on the polarity of the operating current.

The contacts have the same opening and pressure, and are similar in design to those used in the regular Model 9 D. C. relay. The maximum equipment of contacts in the four way relay, shown in Fig. 76, is four normal and four reverse, with four contacting fingers. It is to be noted that when used in connection with wireless signaling on polarized track work, the signal control is broken through one set of con-

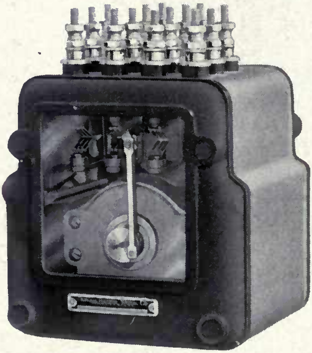


Fig. 76. Three Position D. C. Motor Relay
Four way.

tacts only, while in the polar-neutral relay the control must be broken through both polar and neutral contacts. This same holds true for the track control, which, owing to the decreased resistance of the contacts introduced into the circuit, means that cut-sections can be employed to as great an extent in polarized track circuit work, through the use of this relay, as in the case of neutral track circuits employing the ordinary two position relay.

The relay has several other important features which should be noted. The design is such that the chance of having the polarity reversed by a large flush of current or by lightning is so remote as to be negligible. The relay is not subject to residual magnetism troubles in any way, as its operation depends on current only, and not on electro-magnetic traction. This being the case, the drop away (50 per cent. of the normal pick up) cannot change with time, and once fixed, always remains the same. The overall dimensions are such as to permit its installation in the space required by a D. C. tractive type relay having the same contacting capacity.

TRACTIVE TYPE D. C. RELAYS

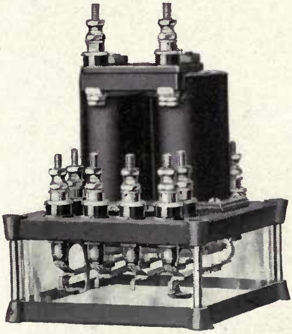


FIG. 77. MODEL 9 D. C. SHELF RELAY
Four way.

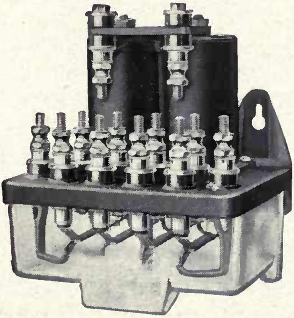


FIG. 78. MODEL 9 D. C. WALL RELAY
Four way.

MANIPULATION

FROM	TO	REVERSE					
1	48	21	1				
2	48	21	PB	2			
3	48	27	24	25	22	3	
4	51	22	4				
4	48	27	24	25	22	PB	4
5	51	20	5				
6	51	27	6				
42	B	20	42				
43	D	27	43				
44	B	20	PB	44			
44	C	22	44				
44	D	27	PB	44			
45	A	21	45				
45	C	27	24	25	22	45	
48	H	67	48				
49	F	70	66	64	68	49	
50	F	70	66	64	68	PB	50
50	H	67	PB	50			
51	E	70	51				
51	F	68	51				
51	G	72	51				
83	45	67	83				
84	45	70	66	64	68	84	
84	42	68	84				
85	42	70	PB	85			
86	42	70	86				
87	42	72	PB	87			
88	42	72	88				

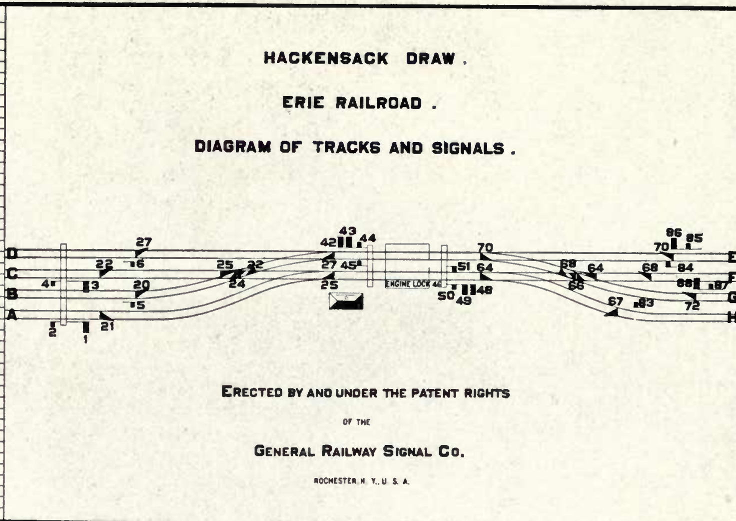


FIG. 79. TRACK DIAGRAM AND MANIPULATION CHART. HACKENSACK DRAW BRIDGE, ERIE R. R.

TRACK DIAGRAMS AND MANIPULATION CHARTS

To facilitate the manipulation of the levers of the interlocking machine, it is customary to mount within full view of the leverman a diagram of the track layout showing the relative location of all interlocked switch and signal functions, also a chart listing the various routes through the plant and the order in which the levers are to be moved in setting up each of these routes. By referring to the chart, the leverman is guided in manipulating the levers in the sequence imposed by the mechanical locking between levers, thus aiding him greatly in the handling of the traffic passing through the plant.

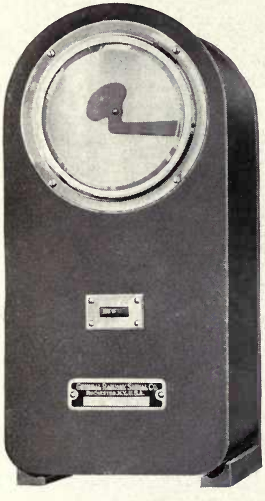


Fig. 80

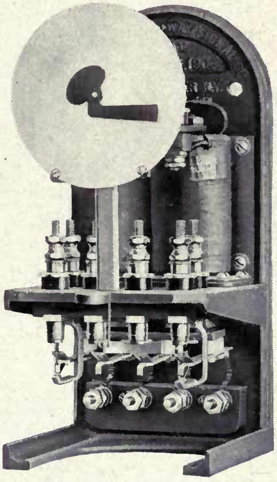


Fig. 81

Model 9 D. C. Indicator
Four way.

The track diagram and manipulation chart are usually combined in one plan and mounted in a single frame, unless their combined size is prohibitively large, in which case they are framed separately.

INDICATORS

For a long time it has been customary to give to the leverman an indication of the trains approaching the interlocking plant; with the advent of route locking and the semi-automatic control of signals, and the consequent general use of track circuits within the interlocking limits, this practice has been extended to indicating at the interlocking station, the

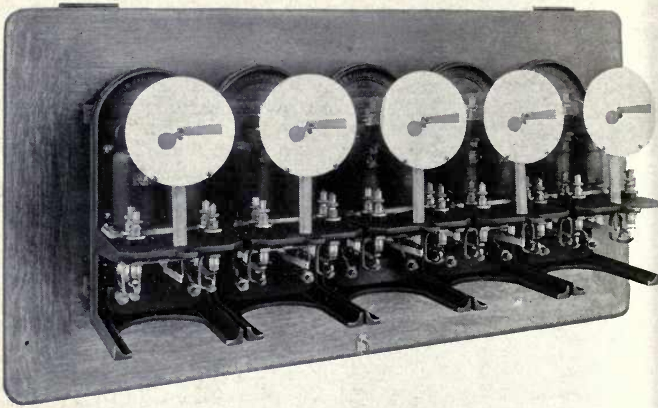


Fig. 82. Model 9 D. C. Indicator Group
Cover removed.

condition of all the track sections within the plant. This supplements the information given by the track diagram and manipulation chart, and adds considerably to the facility with which the traffic is handled.

The approach sections are usually repeated by disc indicators and the different track sections between the home signal limits by semaphore indicators. These are generally located on the wall of the operating room near the track diagram,

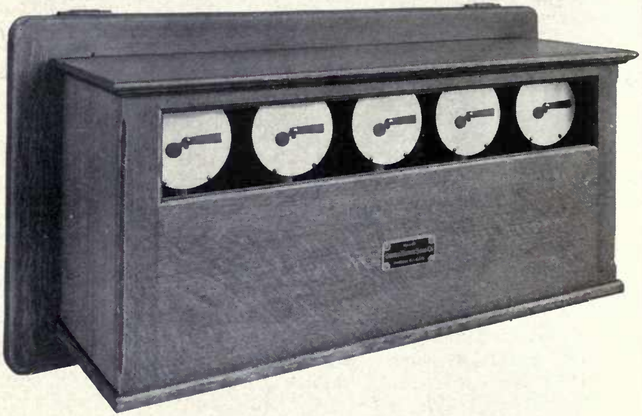


Fig. 83. Model 9 D. C. Indicator Group

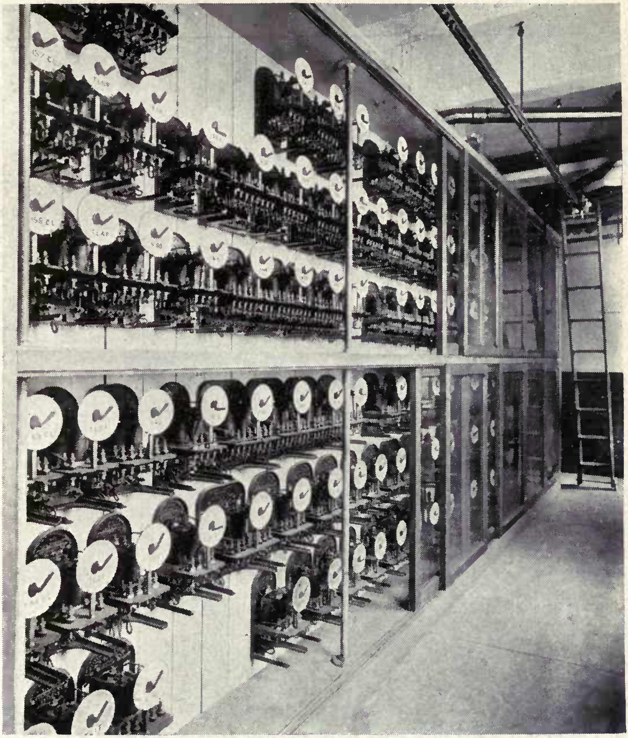


FIG. 84. MODEL 9 D. C. INDICATORS. LAKE STREET INTERLOCKING PLANT, CHICAGO TERMINAL, C. & N. W. R'Y

being mounted either separately with individual covers or on a common frame with a single cover. The indicators, as shown by Figs. 81 and 82, may be equipped with contacts and thus perform the functions of a relay in addition to those of a repeater.

ILLUMINATED TRACK DIAGRAMS

A method of indicating the occupancy or non-occupancy of the various track sections, rather more elaborate than by the use of repeating indicators, is through the employment of the illuminated track diagram. This type of indicator is of great assistance on extremely busy plants where it is necessary to know when a train has cleared each route or

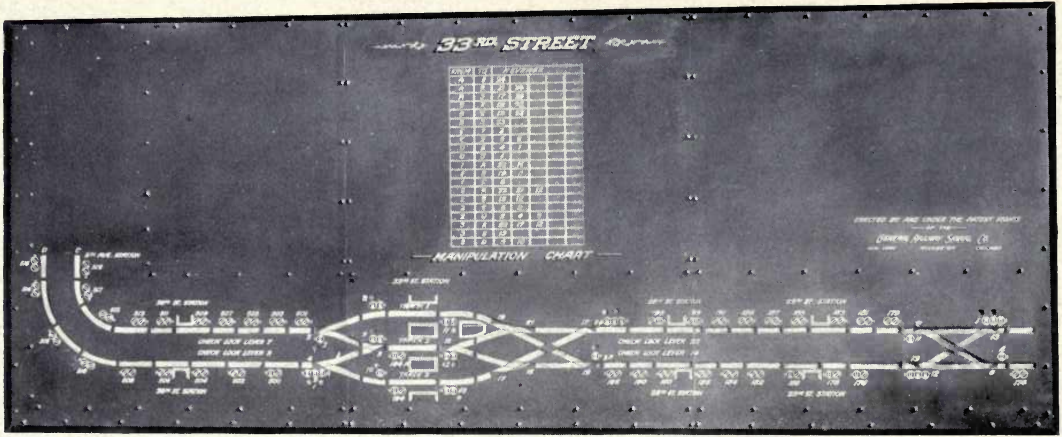


Fig 85. Illuminated Track Diagram and Manipulation Chart. Thirty-third Street Station, Hudson Tunnels, H. & M. R'y

section of a route, in order to promptly prepare for the next train movement. It is practically essential wherever it is not possible for the operator to obtain a clear view of the tracks within the interlocking limits.

The device consists of a boxlike frame, the front or cover of which is glass, painted to leave transparent the track layout and to show the relative location of the various switch and signal functions. One or more miniature incandescent lights are located in a slot or channel behind each track section, the condition of the track circuit usually being indicated by whether or not the bulbs are lighted.

G. R. S. ALTERNATING CURRENT APPLIANCES

DESCRIBING A. C. RELAYS AND THEIR USE IN INTERLOCKING WORK; ALSO SINGLE AND DOUBLE RAIL A. C. TRACK CIRCUITS, AND TRANSFORMERS

ALTERNATING CURRENT RELAYS

THE following pages have been written with the object of acquainting those interested in this type of apparatus with the principal characteristics and proper application of the various alternating current relays manufactured by the General Railway Signal Company.

Points to be Considered in Selecting an Alternating Current Relay

In selecting any alternating current relay for a given purpose, the following should be taken into consideration:

First—Is the device to be used as a track relay or a line relay?

If it is to be employed as a track relay, in all probability it will be exposed to the influence of traction or foreign currents, and must, therefore, be of such design that it will not respond to currents other than that intended for its operation. Furthermore, if the track circuits are very long or the ballast very bad, or if the relay is to be located a long distance from its point of connection to the rails, the relay should necessarily require very little energy from the rails in order to avoid cut sections or undue energy consumption. On the other hand, when the opposite conditions exist, these relays need not be so highly efficient and consequently may be smaller and less expensive.

If required for use as a line relay the device will rarely be installed where it will be exposed to the influences of foreign or traction currents, and when such is the case, can be of simpler, smaller, and less expensive design.

Second — Is two or three position operation required?

In this connection it should be noted that the amount of line wire can frequently be reduced by the employment of relays which have normal, reverse, and de-energized positions. To secure the equivalent of this using two position relays it may be necessary to install twice as many relays and additional line wire. A concrete example of this is the application of three position relays to polarized track circuit work in which the caution and clear positions of a signal are given over the track rails by reversing the polarity, and without the use of line wires at all.

Third — How many and what kind of contacts is the relay to have?

It frequently happens that as many as ten or twelve contacts are required and that these contacts must carry at comparatively high voltage a large amount of current; in other cases but few contacts and these carrying very light currents are necessary. Furthermore, contacts equipped with "magnetic blowouts" may be needed to extinguish arcs which otherwise would be established in the handling of heavy direct currents. These are features which often determine the selection of the relay.

Fourth — Generally speaking, the question of whether a relay is to be of high or low efficiency, and whether it would pay to spend more or less for it, should be decided on the same basis that is used in selecting any piece of apparatus, viz: having determined the total cost of the device in place, including any necessary auxiliary devices, it is then proper to estimate the cost of the energy required for its operation, and that relay which will answer the purpose and cost the least, considering first cost, energy consumption, maintenance charges, interest, and depreciation, should, of course, be the one to use.

Model 2 Form A Polyphase Relay

The Model 2 Form A relay is especially designed for powerful and efficient operation on very long track circuits. As

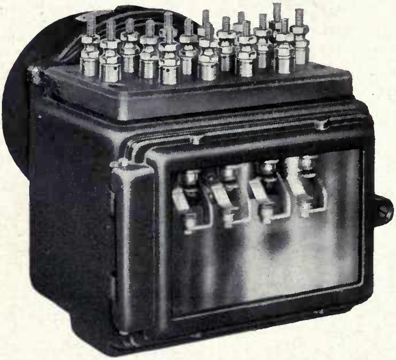


Fig. 86. Model 2 Form A Polyphase Relay
Four way.

an evidence of this efficiency, it may be pointed out that with minimum energy consumption it has given perfect operation on track circuits of from three to four miles in length, and with ballast conditions far from favoring good track circuit operation.

The relay is operated by a polyphase motor, which consists of a non-magnetic rotating shell or "rotor," and fixed inner and outer cores, the outer core being the "stator" on which the windings are placed. These windings are designed and connected so as to produce (with alternating current applied) a rotating magnetic field, which in turn will induce currents in the non-magnetic rotor causing it to operate. (Direct currents cannot produce this rotary field and, therefore, cannot cause operation.) The rotor is ordinarily connected to the contacts through the medium of a pinion and sector arrangement, thereby multiplying the effect of the rotor and permitting the operation of a large number of contacts with a very small amount of energy applied. Furthermore, as it is possible to supply most of the energy to the stator from a local source, only a small amount of energy is required from the rails to cause the relay to operate. These two points permit the operation of very long track circuits without the use of cut sections or undue energy consumption.

The relay is universal in its application, in that it may be wound for operation on steam roads, electric roads using either A. C. or D. C. propulsion, or for operation as a line device. Furthermore, it can be adapted for use on any frequency current, for two or three position operation, and may be made fast or slow acting.

The contacts are unusually heavy in construction and are so designed that any combination of front, back, or front and back contacts can be secured, changes being easily made on the ground if desired. Special contacts equipped with the "magnetic blowout" referred to on page 109 can also be furnished. The contact housing for the four and six way relays accommodate eight and twelve contact fingers, respectively, these controlling eight or twelve independent circuits.

Model 2 Form B Relay

The Model 2 Form B relay operates on the same general principles as the Model 2 Form A, employing the non-magnetic rotor which permits it to operate with the same degree of safety and reliability. It is designed primarily to operate as a line device but may be used in connection with track circuits to a limited extent; for instance, as a track relay for short track circuits on steam roads, or for short double rail track circuits on roads using direct current for propulsion. While the relay's efficiency is approximately but half that of the Model 2 Form A it compares well, nevertheless, with other A. C. relays on the market. It operates on 25 or 60 cycle current, in two or three positions, and can be furnished either slow or quick acting.

The Model 2 Form B relays have about the same overall dimensions as a D. C. relay of the same contact capacity, this feature permitting their installation in housings previously occupied by D. C. relays. The relay is assembled as a shelf or wall type device, as a tower indicator or as an interlocking relay. The contacts are limited to a maximum of four front and two back, or six front and two back, in the four and six way relays, respectively.

Model 3 Form B Relay

In the Model 3 Form B relay, the same construction is used for the housing, contact arrangement, etc., as in the Model 2 Form B. The actuating movement is essentially the same as that of the Model 2 Form B, with the exception that it operates in two positions only and is a single phase device.

Due to this feature the relay does not require the presence of local energy which is sometimes difficult to provide for. The relay is equipped with a non-magnetic rotor and is designed primarily for use in connection with single rail track circuits on direct current electric traction roads.

Model Z Form B Relay

The Model Z Form B relay uses the same housing and is provided with contacts of the same design and arrangement as the Model 2 Form B and Model 3 Form B relays previously described.

The Model Z relays are provided with a bipolar stator, with windings on each of the poles, and a rotary armature so

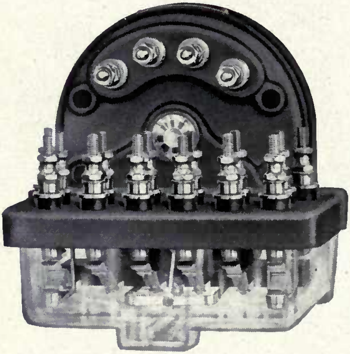


Fig. 87
Model 2 Form B, A. C. Relay
Model 3 Form B, A. C. Relay
Model Z Form B, A. C. Relay
Six way.

shaped that when current (either direct or alternating) is applied to the windings, a uniform torque is produced, which causes the rotor to operate through about ninety degrees. This movement is transmitted by means of a suitable connection to the contacts.

Being operable on direct current, the relay is adapted for line service only. Its exceptionally high efficiency makes it preferable for this type of work where direct current does not exist on the line and where single phase operation is desired. The relay operates in two positions only.

In conclusion, attention is directed to the comparatively few types of relays needed to cover the full range of requirements of A. C. signaling.

It will be noted by reference to the description which has preceded:

First — That but two general forms of construction are employed, viz: the larger, more efficient form (Fig. 86), especially adapted for track circuit work, and the small, moderately efficient form (Fig. 87), especially designed for line circuits and short track circuits.

Second — That but two principles of operation are used, namely: the inductive as employed in the Model 2 and Model 3 relays, and the electro-magnetic as employed in the Model Z relays.

Third — That each form is made in two sizes to accommodate more or less contacts as required.

With these two forms, two principles of operation and two sizes of relays, wound and equipped with contacts as may be necessary, all the requirements of A. C. signaling can be met without resorting to a greater number of types. It will, therefore, be seen that the G. R. S. relay construction has placed A. C. relays, as regards the diversity of types required, on practically the same basis with the relays used in connection with D. C. signaling.

SINGLE RAIL ALTERNATING CURRENT TRACK CIRCUITS

SINGLE rail A. C. track circuits are largely used at interlocking plants in electrified territory. With this type of track circuit, insulated joints are placed in one rail only, the other rail being used in common by the return propulsion current and the signaling current (see Figs. 88 and 89). It will be seen that single rail track circuits are used to best advantage where there are two or more parallel tracks, in that the power or common rail of all these tracks can be bonded together, thus preventing interruption of the propulsion current return in the event of a break in the power bonding in any one of the continuous rails.

ADVANTAGES

The chief advantage of single rail track circuits as compared to the double rail type is in its lesser cost and complication, the double rail circuits requiring the installation of impedance bonds to provide a continuous return for the propulsion current. As there are usually a number of comparatively short track circuits at an interlocking plant, it is seen that the use of double rail track circuits with impedance bonds would be very expensive. It is furthermore true that at many plants, the track arrangement is such that it would be extremely difficult to secure space at the bond locations for their installation.

LIMITATIONS

Traction Return. When single rail track circuits are installed, both rails cannot be retained for traction purposes, as noted above. If the giving up of one rail leaves insufficient return for the propulsion current, the use of single rail track circuits is barred and double rail track circuits would probably have to be employed.

Broken Rail Protection. Single rail track circuits do not give broken rail protection due to the cross bonding required for traction purposes, which provides a number of return paths through the rails of other tracks for the signaling current. On this account the use of single rail track circuits should be restricted to slow speed tracks, such for example as in terminals, or to siding tracks.

Length. The permissible length of single rail track circuits is limited either by ballast conditions, by the traction drop in the return rail between the points of connection of the transformer and the track relay to the common rail, or by the combination of ballast and drop. The Model 2 Form A relay as ordinarily constructed is capable of carrying 10 amperes direct current through its track winding without overheating or being caused to open.

The drop in the common rail has the effect of sending direct current from the common rail through the transformer, through the signaling rail, the track winding of relay and back to the common rail, this effect being maximum when a train is on the transformer end of the track circuit, thereby cutting out the transformer resistance and allowing the full drop to be effective through the signaling rail and relay in series.

In view of the fact that the common return rail has a negligible resistance, there are times when it can be assumed that all of this drop is effective across the relay, and to prevent a prohibitive amount of direct current from flowing through the relay, under ordinary conditions a limiting resistance is added in series with the relay.

If however the track circuit is long or the ballast bad, the traction drop will in all probability be excessive, thereby requiring that the limiting resistance be high, which in turn necessitates that a correspondingly high A. C. voltage be impressed across the rails at the relay location in order to secure operation; this A. C. voltage is limited since as the voltage is increased the current leakage between the rails throughout the length of the track circuit increases very rapidly. To take care of such a condition an impedance having low ohmic resistance to direct current, but high resistance to alternating current, may be shunted across the relay terminals, this permitting a large amount of direct current to flow through the relay and impedance combined without causing more than 10 amperes direct current to flow through the relay; a unit of low resistance is still required, being connected in series with the relay and impedance, this resistance necessarily being in the nature of a grid since it has to carry a comparatively large amount of direct current. With this arrangement the transformer should be designed to stand a large amount of direct current through its secondary winding without having its A. C. voltage seriously affected.

Under the conditions ordinarily found in terminals or where it is permissible to use single rail track circuits, it will be found that the use of a resistance in series with the relay is adequate to secure proper operation, it being necessary only in rare cases to employ the impedance shunted around the terminals of the relay as above described.

Energy Required

The energy required for the operation of single rail track circuits depends upon the amount of traction drop in the common rail and upon the ballast conditions. In an interlocking plant where the track circuits may average 500 feet in length, the energy per track circuit, employing the Model 2 Form A track relay, should not exceed the figures given below:

	Total Energy Required for Track Circuit and Relay Local	
25 cycle current, ...	30 volt amperes	25 watts
60 cycle current, ...	40 volt amperes	30 watts

Note.—The Model 2 Form A track relay, quick acting and designed to stand 10 amperes direct current, has a resistance of about one-half ohm.

Types of Single Rail Track Circuits

In the past the common practice when installing single rail A. C. track circuits has been to locate the track transformer at one end of the track circuit and the relay with its housing and auxiliary apparatus at the other end; this requires that the relay must be repeated into the interlocking station to operate other relays or indicators. A simplified diagram of such a circuit is illustrated by Fig. 88.

In sharp contrast with this is shown in Fig. 89, the method which can be used when a high efficiency polyphase relay such as the Model 2 Form A is employed. By feeding the track circuit from a central source and extending the relay leads

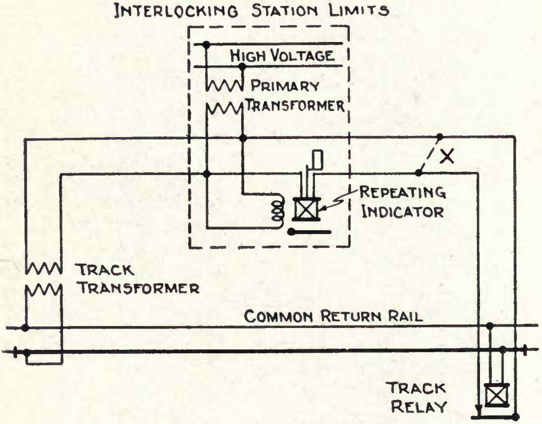


FIG. 88. SINGLE RAIL A. C. TRACK CIRCUIT
Track relay and transformer located at track circuit.

from the track circuit into the station, the amount of apparatus can be cut down, maintenance costs reduced to a minimum, and certain safety features, not obtainable in the other arrangement, secured.

It will be noted that in the central energy scheme, the vital parts of the track circuit are located in the station directly under the eye of the maintainer which permits adjustments to be made under the most favorable conditions. Due to the simplicity and accessibility of this type of track circuit, maintenance is reduced to a minimum.

A considerable amount of apparatus is saved by this kind of an installation, since secondary relays with their track boxes, additional wiring and fusing, are not required: furthermore, the numerous track transformers which otherwise would have to be distributed from one end of the interlocking plant to the other are eliminated due to the circuits being fed from one central point. The resistance of the leads from the track circuit to the relay and transformer, constitute a part of the limiting resistance required in series with these pieces of apparatus.

A safety feature obtainable in the central energy scheme which cannot be overlooked is in the protection against crosses. It will be noted by reference to Fig. 88 that a cross at X will cause false operation of the repeating relay in the station, whereas a similar cross in Fig. 89 prevents, as it should, operation of the relay. Every step toward simplicity is a

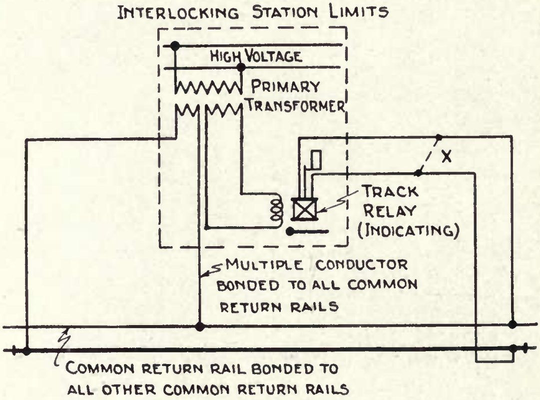


FIG. 89. SINGLE RAIL A. C. TRACK CIRCUIT
Central energy scheme.

step towards safety and this central energy control is the last word in simplicity as regards track circuits.

The high efficiency of the Model 2 Form A relay especially adapts it for this kind of work, the relay requiring but a small amount of current from the rails, while a comparatively large amount is supplied at the station for the local phase of the relay. The relay may be equipped with an indicator blade and located in plain sight of the leverman, thus dispensing with the necessity of repeating indicators which might otherwise be required for this purpose.

TYPICAL INSTALLATION OF THE CENTRAL ENERGY SCHEME

Fig. 90, which is typical of a large G. R. S. installation, illustrates the extension of the principle of Fig. 89 into the complete wiring required in connection with this type of track

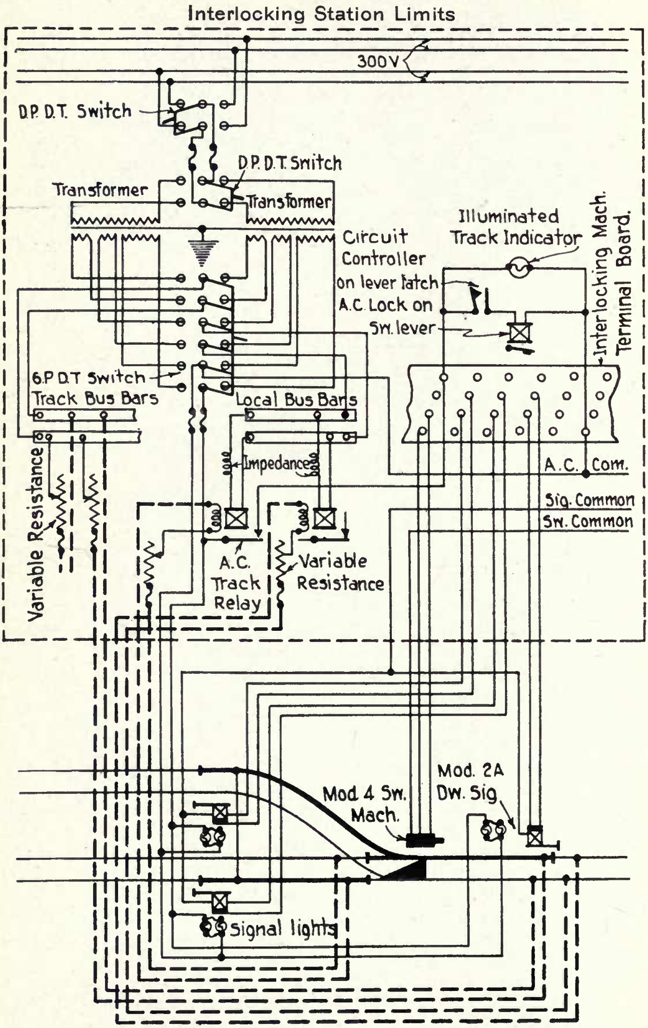


FIG. 90. SECTION OF INTERLOCKING PLANT
Showing use of central energy scheme for track circuit control.

circuit work. It also indicates the control between the interlocking machine and the switch and signal functions in the given section of track, and shows the method of controlling the switch lever locks and track indicators through the track relay.

The track relays and transformers are shown located in the station, the latter being installed in duplicate to prevent any interruption of service should anything happen to one of the transformers. It will be noted that the transformers, besides feeding the track circuits, are used to furnish energy for the signal lighting and the operation of all A. C. apparatus. The track winding of these transformers is brought to a buss bar on the distributing switchboard, the individual leads of the various track circuits being connected to this buss. It is general practice where the track circuits vary sufficiently, or where any of them are located far enough from the station to require much more voltage than the others, to provide the track winding of the transformer with a number of taps which are carried to different buss bars, the individual leads of the different track circuits being taken from one buss or the other as required.

IMPEDANCE BONDS FOR DOUBLE RAIL ALTERNATING CURRENT TRACK CIRCUITS

WHEN it is desired to install A. C. track circuits and both rails must be retained for propulsion purposes, double rail track circuits, such as are shown by the typical circuit, Fig. 238, must be employed. It will be noted that the track is divided into sections of varying length by

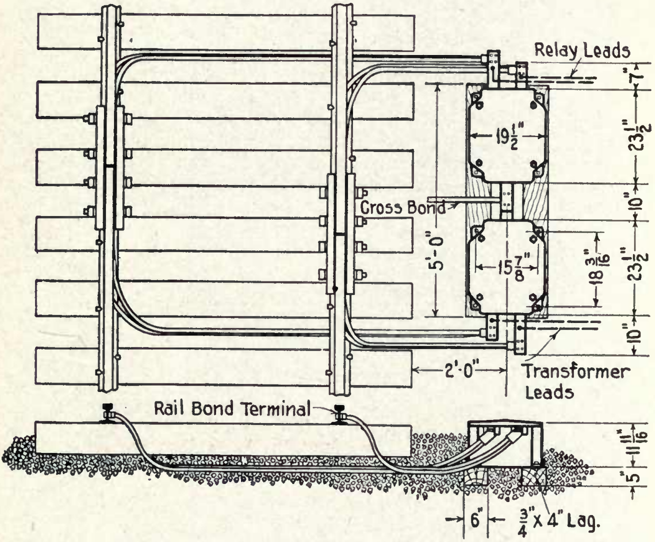


FIG. 91. METHOD OF INSTALLING SIZE 1 FORM C IMPEDANCE BONDS

means of insulated rail joints. Impedance bonds are installed at such locations for the purpose of providing around the joints a low resistance path for the return D. C. propulsion current, while not permitting the passage of the A. C. signaling current.

The bonds consist of a few turns of heavy copper wound about, but insulated from, a laminated iron core, the connections to the rails being so made that the traction current has no magnetic effect on the bond, provided an equal amount is flowing in each of the rails. If, however, more current is flowing in one rail than in the other, there will be a tendency to saturate the iron core and thereby reduce the impedance of the bond. This effect, which is called "unbalancing," is limited by introducing an air gap into the magnetic circuit, the bonds ordinarily being designed to stand 20 per cent. unbalancing without a decrease of more than 10 per cent. in impedance.

The size of the bond to be installed is dependent upon the amount of current the bond will have to carry, the impedance to which it must be wound (this being more or less dependent upon the length of the track circuit), and upon the amount of unbalancing to be taken care of. Where good traction bonding can be maintained a less amount of unbalancing can be figured upon, and hence a smaller size of bond employed.

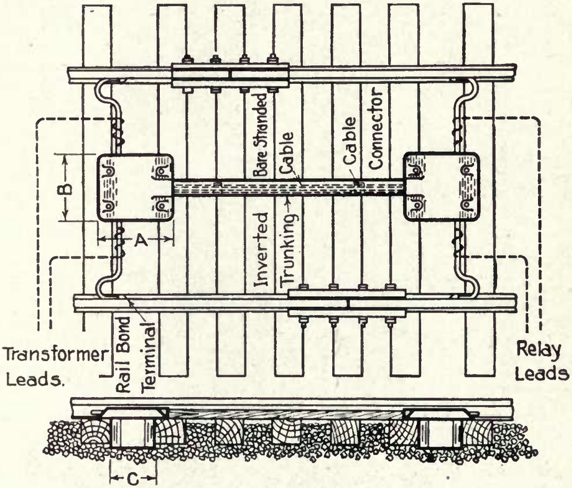


Fig. 92. Method of Installing Size 2 Form B and Size 3 Form A Impedance Bonds

Dimension	Size 2 Form B Bond	Size 3 Form A Bond
A	20½ inches	18¼ inches
B	24½ inches	17½ inches
C	13⅜ inches	11⅝ inches

The Size 1 Form C bond, which is the largest, is installed only where the heaviest traffic requirements are to be met, the size of the bond requiring that it be located outside of the rails. The Size 2 Form B and Size 3 Form A bonds are of such dimensions as to permit their being installed between the rails. These smaller bonds are furnished with sloping covers to prevent their being caught by dragging train parts, and are especially designed to have their leads brought out of the case in a manner to facilitate connection to the rails.

TRANSFORMERS

High Tension Line Transformers

THE Type L transformer is a single phase, oil immersed, self cooled, pole type transformer, designed to step down the transmission line voltage (6,600 volts maximum) at signal and track feed locations, to the voltage required for the operation of the signal system.

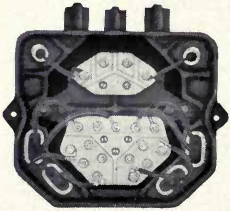


Fig. 93. View of Type L Transformer Showing Terminal Boards

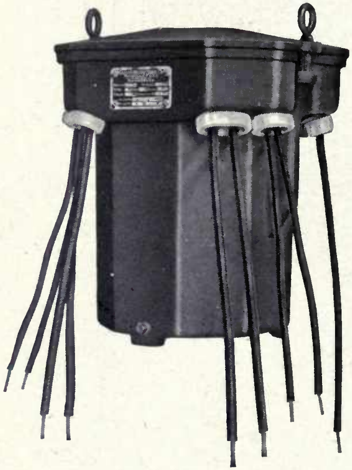


Fig. 94. Type L High Tension Line Transformer

The combinations in which these transformers are made up are as follows:

1. High tension primary winding and low tension secondary winding for feeding relay locals, signal mechanisms, and lights.
2. High tension primary winding and low tension secondary winding for feeding track circuits.

3. High tension primary winding and low tension secondary windings, one for feeding relay locals, signal mechanisms and lights, and one or two for feeding track circuits.

The primary or high tension winding may be equipped with 5 and 10 per cent. taps brought to a suitable porcelain terminal block, which ordinarily is located below the oil level to minimize the liability of lightning arcing from post to post. The secondary leads and taps are brought to a separate porcelain terminal board located above the oil level.

The transformer windings are contained in a cast iron, water-proof case, which is fitted with lugs to take the hanger irons necessary for mounting.

These transformers are built with the same relative polarity and are so constructed that reversing the polarity of the track feed may be accomplished on the terminal block inside the transformer without changing the permanent exterior circuit connections.

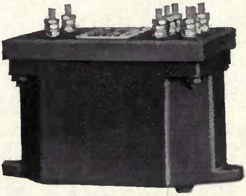


FIG. 95. TYPE K SECONDARY TRACK TRANSFORMER

Core losses and copper losses are lower and the efficiency higher than usually is obtainable on this special class of transformers. Good regulation on low power factor, low exciting current and high insulation (insulation tests being 50 per cent. above A. I. E. E. standards) are features which combine to form an exceptional transformer in point of long life and safety. The transformer design is strictly in accordance with R. S. A. specifications.

SECONDARY TRACK TRANSFORMERS

The Type K secondary track transformer as illustrated by Fig. 95 is of the air cooled type and is especially designed for feeding individual track circuits, being used, however, to some extent, in connection with low voltage tungsten lighting.

The transformers are ordinarily made up with one high tension primary winding and one low tension secondary winding, this latter being provided with taps for the adjustment of the track circuit feeds. The primaries are wound for any voltage up to 440 as specified and as ordinarily installed are connected to the low tension secondary of the line transformer. These connections can be made and the track transformer housed in the relay box ordinarily installed at signal locations.

The cover of the transformer is provided with binding posts for both high and low tension windings. The case is of cast iron, light in weight, and is provided both with lugs for hanging, and with feet to permit of the device being mounted as desired.

The same exceptional efficiency, regulation, and low exciting current are obtained in this class of transformer as in the Type L transformers, previously described.

SIGNAL LIGHTING AT INTERLOCKING PLANTS

COVERING RECOMMENDED PRACTICE FOR ELECTRIC LIGHTING AS TO THE ARRANGEMENT OF LAMPS, SOURCE OF POWER, AND PRECAUTIONS TO OBSERVE

SIGNAL LIGHTING AT INTERLOCKING PLANTS

THE question as to whether oil or electricity is to be used for lighting the signals at electric interlocking plants, depends on what is most economical and satisfactory under the particular conditions existing at each separate plant.

In many cases a decision as to the type of lighting best adapted to a given plant can be easily reached. For example: If commercial power of proper voltage is available at low cost, or if alternating current is employed in connection with the signaling, it will undoubtedly be found desirable to light the lamps electrically; this is especially so if the plant is a very large one, as at such a point the oil lamps would require a special force of lampmen for their maintenance. On the other hand, if commercial power is not available or can be secured only at a high rate, or if the plant is so small that oil lamps could be cared for by the force regularly employed, it will probably be found most economical to use oil lighting.

In cases where the course to be followed is not so evident, a careful estimate of the initial expense involved and of the cost of operation and maintenance, should be prepared before a decision is reached. In the case of oil lighting it is merely necessary to consider the cost of the lamps, oil, maintenance, etc. In the case of electric lighting, however, a number of other considerations enter into the problem as outlined on the following pages.

Type and Arrangement of Bulbs in Signal Lamps

The bulbs used in this type of work are ordinarily of low candle power, it having been found that ample light is secured from bulbs of two or four candle power. When the lighting is operated at 110 volts, the carbon filament type is installed, it being considered that metallic filament bulbs of such low candle power are too frail to be reliable when designed for operation on this voltage. Where it is possible, however, to furnish current at a potential of from 6 to 12 volts, the high efficiency of the metallic filament type can readily be made use of.

POWER REQUIRED FOR OPERATION OF INCANDESCENT LAMPS

Candle Power	Carbon Filament		Metallic Filament	
	110 Volts	55 Volts	10–13 Volts	4–6 Volts
	Watts	Watts	Watts	Watts
2	10	10	..	2½
4	20	20	5	5

Note.—Values approximate.

In determining the arrangement of the bulbs in each signal lamp, the first consideration is to insure the signals against ever being without light. On this account, general practice has been to have each signal lamp contain two bulbs, connected in multiple, it being highly improbable that both will burn out at the same time. The reduced brilliancy of the signal light, resulting from the burning out of one of the bulbs, causes the failure to be quickly detected and permits the necessary renewal to be made at once.

Where two bulbs, burning in multiple, give more than the amount of light required, an economy can be effected without sacrificing reliability by employing "cut in" relays which permit the burning of but one of the bulbs at a time. The coil of this "cut in" relay is connected in series with the bulb that is to burn normally, a back contact on the relay being arranged to connect the reserve bulb across the lighting mains in the event of failure of the one in service.

Another way to reduce the energy consumption and still retain the necessary reserve, is to use the high efficiency metallic filament bulbs connected in multiple. As stated above, a low candle power bulb of this type to be reliable must be operated on low voltage.

Normal Source of Power and the Necessary Reserve

Having touched upon the type and arrangement of the bulbs to be used in signal lamps, the next consideration should be with regard to the normal power supply and what reserve should be provided to keep the lights burning in case of emergency.

It is recommended as good practice that the signal lights should be operated from a commercial source, the control being arranged so that the lighting systems will be quickly transferred on to the 110 volt interlocking battery in the event of failure of the commercial power. It will be seen that this use of the interlocking battery as a reserve restricts the lighting to operation on 110 volts. The commercial power may be either alternating or direct current and will in all probability be delivered at 110 or 220 volts. If this potential is 220 volts, it is, of course, necessary to install a motor generator set, transformer, etc., to reduce the voltage to that required by the lighting system.

Where a reliable source of alternating current is available, such, for instance, as can be obtained when the interlocking plant is located in A. C. automatic signal territory, the reserve battery is not considered necessary, and this permits the lighting system to be operated at any voltage desired. In such a case low voltage metallic filament lamps can be operated, transmission about the plant being made at a higher voltage, thus avoiding the necessity of installing large lighting mains. In this connection it is to be noted that low voltage lighting should be restricted to points where the current supply is absolutely reliable, except in the case of a plant with comparatively few signals, at which plant a low voltage battery of suitable capacity is available for use as a reserve.

In case commercial power, of the proper voltage, or signaling power cannot be secured, the lights should then be operated from the charging generator, provision being made to transfer the lights onto the interlocking battery in case of failure of the generating unit. Attention is called to the undesirability of lighting from this source unless either the charging unit or interlocking battery is installed in duplicate, since if only one generator and one battery were employed, the capacity of the battery would have to be excessively large to provide sufficient reserve against the failure of the charging generator, such a failure in all probability being of longer duration than would be the case with commercial power.

PRECAUTIONS

In operating the lighting system from a charging generator great care should be used to see that the normal voltage of the lamps is never exceeded, since the bulbs will be quickly burnt out if subjected to an excess voltage. This increased voltage always exists when the charging generator is supplying current for the lighting system at the same time it is charging the interlocking battery; therefore, a regulating device must be provided to maintain the voltage on the lamps at the normal point. This device ordinarily is a hand operated rheostat which has sufficient regulation to permit the voltage to be kept at normal. It will be seen that the device will require the maintainer's attention at frequent intervals; this, however, cannot be considered serious, as under such conditions the interlocking battery would never be charged at night except in case of emergency. Where duplicate batteries are employed, a regulating device is not required, as the combination of switches on the power board can be so arranged that it is impossible to serve the lighting circuits from the battery that is being charged.

Precaution respecting cross protection should be observed whenever the interlocking battery may be called upon to furnish current for the lighting system. At plants where the operating switchboard is equipped with the cross protection circuit breaker shown in Fig. 24 (both positive and negative battery connections being broken through the circuit breaker contacts), the signals can be electrically lighted from the interlocking battery without endangering the proper operation of the switches, signals, or other functions of the plant. If, however, it is proposed to electrically light the signals of an existing G. R. S. plant at which plant the old type of circuit breaker (Sec. 1, Elec. Int. Cat., page 280) is installed, it is strongly recommended that the operating switchboard be equipped with the double pole circuit breaker (Fig. 24) and the circuits rearranged to embody the principles of the wiring shown on page 88. The lighting mains under no condition should be controlled through the circuit breaker.

Recommendations

It is recommended that two bulbs always be installed in each signal lamp, burning in multiple or operated in connection with a "cut in" relay.

Regarding the source of power, it is recommended as good practice that commercial power be employed, providing arrangements are made to cut the lighting system onto the interlocking battery in case of failure of the commercial source.

Where the interlocking plant is located in A. C. automatic signal territory the lighting may be operated on any voltage desired. At such a point high efficiency metallic filament lamps can readily be operated. No reserve is necessary, in view of the fact that the signal transmission line is always thoroughly protected against power failure.

Where neither commercial power nor A. C. signaling current is available, the signal lighting may be electrically operated from the charging generator, providing the interlocking battery is (or batteries are) of sufficient capacity to insure the continuous operation of the interlocking and lighting systems through any period of time necessary to repair a failure on the part of the charging unit.

In all cases where storage batteries may be called upon to furnish current for the lighting circuits, regulating apparatus must be installed to permit the current from such battery to be delivered to the lighting mains at normal voltage during a charging period.

Whenever the interlocking battery serves as a reserve, the circuits and apparatus on the operating switchboard must be such that operation of the lighting system will in no way endanger cross protection.

ELECTRIC LOCKING AND CHECK LOCKING

GIVING A DESCRIPTION OF THE VARIOUS TYPES OF CIRCUITS AND THEIR APPLICATION TO ELECTRIC INTERLOCKING WORK

ELECTRIC LOCKING

ELECTRIC locking as defined by the Railway Signal Association consists of "the combination of one or more electric locks and controlling circuits by means of which levers in an interlocking machine, or switches or other devices operated in connection with signaling and interlocking, are secured against operation under certain conditions."

Electric locking is a development of the tendency in railway signaling practice to constantly decrease the manual control of all functions and to increase the automatic control. The first important step along this line was the operation of switches and signals through the medium of interlocked levers concentrated in a central machine. The real beginning of electric locking, however, was in the installation at mechanical plants of locking circuits which were to prevent the leverman from changing the route in the face of an approaching train. This was followed by a step which had its inception in the all-electric interlocking system: namely, section or detector locking which was designed to afford safety to a train from the time it passed the home signal location until it cleared the limits of the interlocking plant. As first installed in connection with electric interlocking, the switches and derails in a given track section were prevented from being thrown while a train was on that track section, by interrupting the current supply to those functions by means of a relay controlled by the track relay of the section in question. At the present time this method of control is not generally used with the all-electric system, having given way to the practice of equipping each switch and derail lever with electric locks, properly controlled by the various track sections.

Ever since the time of those first successful installations, the signal men of the country have become more and more alive to the fact that safety of railway operation could be much further assured by the development of this principle of automatically preventing the operation of functions which might endanger the safety of trains approaching or passing through interlocking plants. In fact, at the present time electric locking has come to be considered by many a necessary adjunct to an interlocking plant.

Due to the rapidity of the development of the art, a wide range of methods has been used to accomplish the same result; the principles involved, nevertheless, have been so nearly uniform that it has become possible to determine the elements that enter into good practice. For instance, it will be found that it should always be possible to restore the home signal to the normal position, even though it may not be desirable to release the route beyond. Also in case of emergency, release of the route is generally permitted through the use of a time release or hand switch; the circuits are such that when the device has been operated to secure the desired

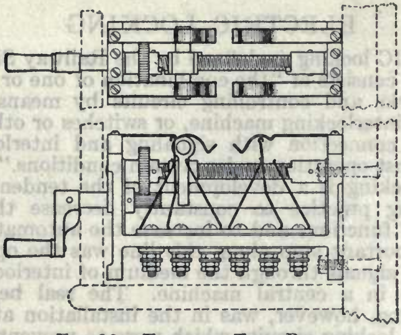


FIG. 96. ELECTRIC TIME RELEASE

release, some circuit essential to the operation of either switch or signal functions will be broken, thus necessitating that the time release or hand switch be returned to its normal position before operation of the switches or signals affected can be resumed.

Based on the above, the Railway Signal Association has classified Electric Locking in the following manner:

"SECTION LOCKING. Electric locking effective while a train occupies a given section of a route and adapted to prevent manipulation of levers that would endanger the train while it is within that section."

An illustration of section locking is given in Fig. 97, showing the manner of controlling the locks with which the switch levers are equipped. As the levers are locked in either the full normal or full reverse position, it will be seen that the

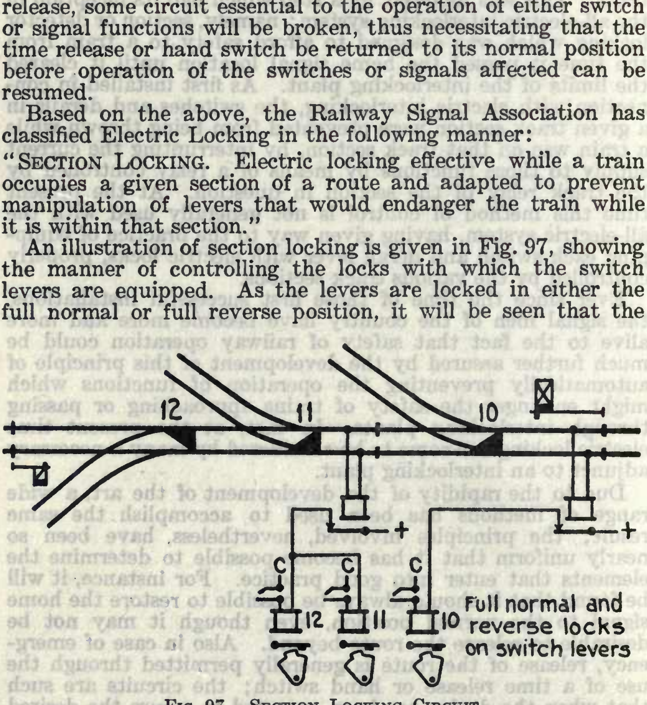


FIG. 97. SECTION LOCKING CIRCUIT

operator is prevented from changing the position of the switches or derails in a given section during such time as that section is occupied or fouled by a train.

"ROUTE LOCKING. Electric locking taking effect when a train passes a signal and adapted to prevent manipulation of levers that would endanger the train while it is within the limits of the route entered."

Route locking is a development of section locking in which the switches and derails in all sections of any route are locked

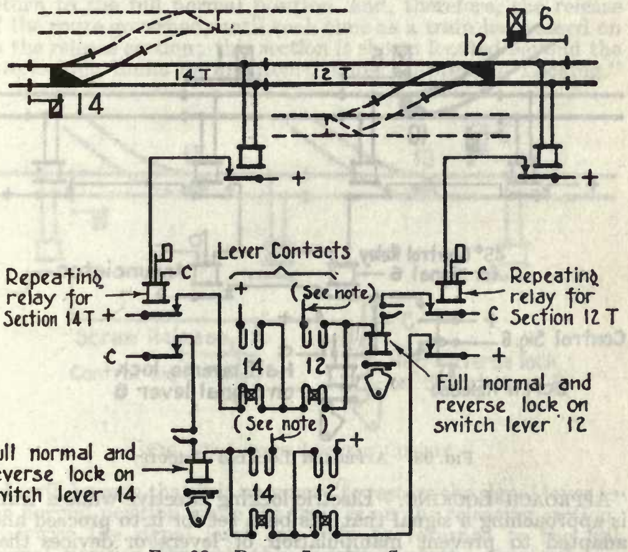


FIG. 98. ROUTE LOCKING CIRCUIT

NOTE.—To positive battery through lever contacts and relays as determined by the layout of track indicated by dotted lines.

from the time a train enters that route until such time as the route is cleared. An illustration of route locking applied to a simple layout is shown in Fig. 98. It is evident that the circuits become somewhat complicated when used in connection with an interlocking where the routing of each signal may extend over a number of combinations of track sections.

"SECTIONAL ROUTE LOCKING. Route locking so arranged that a train, in clearing each section of the route, releases the locking affecting that section."

This is a further development of section locking in which the functions in all sections in a given route are locked as soon as the train has passed the home signal, the functions in each section, however, being released behind the train as soon as the train has passed out of the section.

The installation of sectional route locking has been largely restricted to points such as congested terminals where the maximum number of traffic movements is demanded with a maximum of protection. Due to its being little used, and on account of the rather complicated circuits involved, no attempt has been made to show any typical illustration of the circuits required in such work.

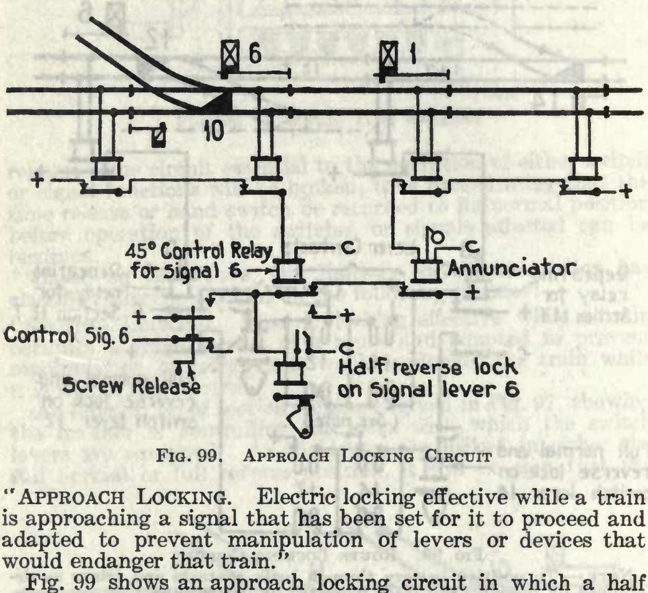


FIG. 99. APPROACH LOCKING CIRCUIT

"APPROACH LOCKING. Electric locking effective while a train is approaching a signal that has been set for it to proceed and adapted to prevent manipulation of levers or devices that would endanger that train."

Fig. 99 shows an approach locking circuit in which a half reverse lock on the home signal lever, through the medium of the locking between the signal and switch levers, prevents the release of the route during such time as the lock is de-energized. The locking becomes effective after the signal for the route has been cleared and the train has passed a predetermined point, which in Fig. 99 is the annunciator section; the locking is released as soon as the train passes the home signal.

It will be noted that in Fig. 99 no protection is given after the train has passed the home signal, i. e.— no route locking protection is afforded. Protection can be given through the plant by releasing the signal lever in the first section beyond the limits of the plant instead of on the forty-five degree control relay.

"STICK LOCKING. Electric locking taking effect upon the setting of a signal for a train to proceed, released by a passing train, and adapted to prevent manipulation of levers that would endanger an approaching train."

Stick locking in reality is only another form of approach locking, being different in that it becomes effectve on the reversal of the home signal lever and does not further depend on the approach of a train.

Fig. 100 shows a stick locking circuit in which the half reverse lock, with which the signal lever is equipped, prevents its return to the full normal position, and, therefore, the release of the route governed, until such time as a train has passed on to the release section; this section is shown located beyond the interlocking limits as mentioned under "Approach Locking."

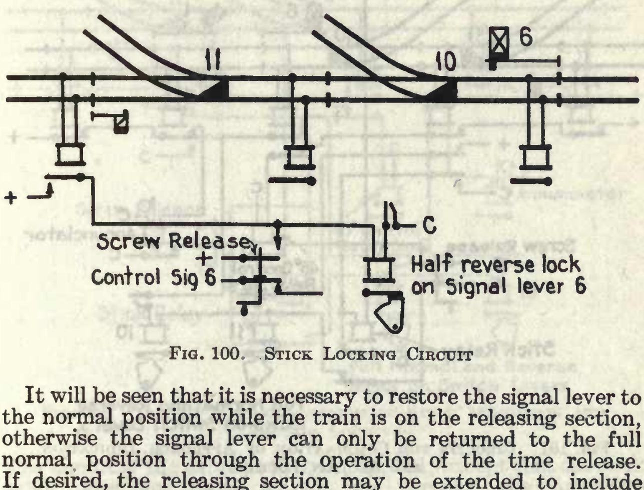


FIG. 100. STICK LOCKING CIRCUIT

It will be seen that it is necessary to restore the signal lever to the normal position while the train is on the releasing section, otherwise the signal lever can only be returned to the full normal position through the operation of the time release. If desired, the releasing section may be extended to include the several track sections in the route so that the lever may be restored to the normal position any time the train is within the limits of the route.

"INDICATION LOCKING. Electric locking adapted to prevent any manipulation of levers that would bring about an unsafe condition in case a signal, switch, or other operated device fails to make a movement corresponding with that of the operating lever; or adapted directly to prevent the operation of one device in case another device, to be operated first, fails to make the required movement."

As an illustration of this type of locking may be taken any electrical device, which is designed to indicate the correspondence of position between a unit and its controlling lever. The simplest example is the indication of the position of a semaphore blade by means of a lock or other device on the governing lever, the control of this lock being carried through the circuit breaker on the signal. The well-known dynamic indication of the all-electric system is a striking example of indication locking.

It will be found that with the exception of certain forms of indication locking, such as the dynamic indication, the different basic forms of electric locking as outlined above are seldom used alone, but in combinations.

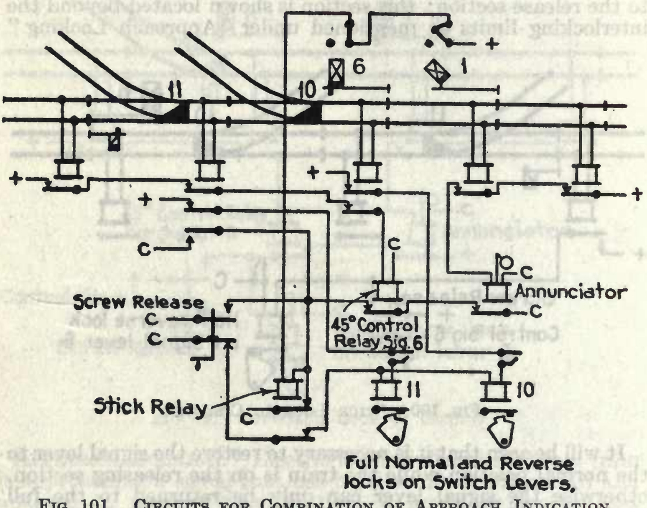


Fig. 101. Circuits for Combination of Approach, Indication and Section Locking

Fig. 101 illustrates the use of an approach locking circuit in conjunction with section locking, and with indication locking for distant signal No. 1. In this circuit the control is secured by equipping the switch levers with electric locks governed by a stick relay. The locking becomes effective when signal No. 6 is cleared but is capable of being released by the return of lever No. 6 to the normal position, providing a train has passed into the releasing section, or providing no train is on any of the track sections repeated by the annunciator and the forty-five degree control relay for signal No. 6. This circuit does not require that the lever be returned to the normal position while the train is on the releasing section.

If this feature is desired the control may be broken through the contacts on lever No. 6 instead of through the circuit breaker of the signal.

The indication locking feature consists of carrying the control of the stick relay through the circuit breaker of distant signal No. 1 to prevent release of the route under any condition if signal No. 1 is not in the caution or stop position.

Fig. 102 illustrates a similar arrangement of tracks and signals, with circuits providing stick locking, section locking, and indication locking. It is to be noted that in every particular

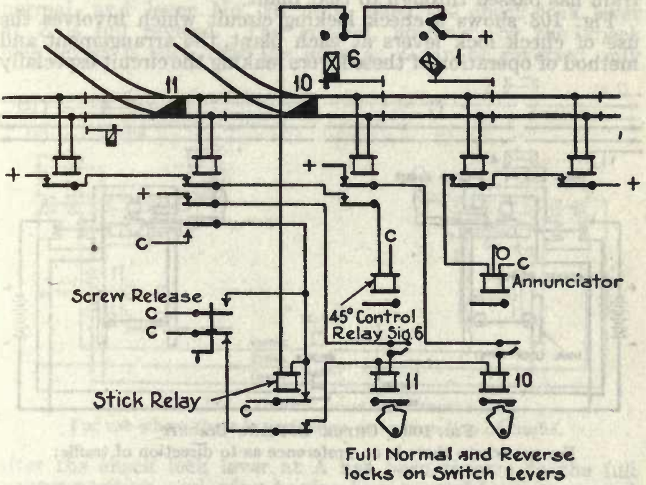


FIG. 102. CIRCUIT FOR COMBINATION OF STICK, INDICATION AND SECTION LOCKING

this circuit is the same as that in Fig. 101, except that the stick relay does not have a pick up through the forty-five degree control relay and the annunciator in series; the omission of this wire classes the circuit under "Stick Locking." The locking becomes effective upon the clearing of signal No. 6 and is released by a train on the clearing section or by operation of the time release.

CHECK LOCKING

WHEN interlocking plants are located a comparatively short distance apart, it is advisable and frequently necessary to install what is known as "Check Locking," which enforces coöperation between the levermen at the two plants in such a manner as to prevent opposing signals, governing over the same track, from being at proceed at the same time. Furthermore, after a signal has been cleared and accepted by a train, check locking prevents an opposing signal at the adjacent interlocking plant from being cleared until the train has passed through to that plant.

Fig. 103 shows a check locking circuit which involves the use of check lock levers at each plant, the arrangement and method of operation of these levers making the circuit especially

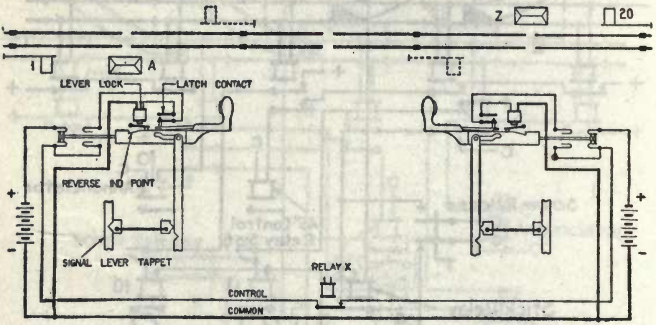


FIG. 103. CHECK LOCKING CIRCUIT
For use where there is no preference as to direction of traffic.

adaptable where there is no preference as to the direction of traffic. The signal levers at each station, governing movements over the intervening track, are so interlocked with the check lock levers in their respective machines, that they may not be moved from their full normal position until their respective check lock levers have been moved to the full reverse position. By reference to Fig. 103 it will be seen that the check lock levers are so controlled that but one of them can be in the full reverse position at the same time. Therefore, it is impossible for signals No. 1 and No. 20 at stations A and Z, respectively, to be displayed at proceed at the same time.

The control circuit for the check lock levers is shown broken through relay X, which represents the track relays for the sections between signals No. 1 and No. 20. This prevents a check lock lever being thrown to the full reverse position and, consequently, any traffic movement from being made during such time as these sections are occupied. The release of either lever in moving to the reverse position is effected by current taken from the battery at the far end of the circuit.

The check locking circuit shown in Fig. 104 is designed for operation when there is a preference in the direction of traffic, since traffic movements can normally be made from A to Z without any interference from the check locking, it being necessary, however, when making a movement from Z to A (against traffic) to operate both check lock levers.

Each station is equipped with a check lock lever so interlocked with signal levers No. 1 and No. 20, that lever No. 1 is free to be moved only when the check lock lever at A is full normal, and lever No. 20 only when the check lock lever at Z is full reverse. The control, however, of the check lock levers is such that the lever at Z can be reversed only

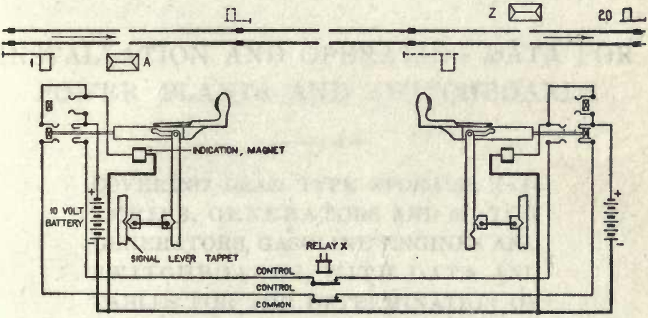


FIG. 104. CHECK LOCKING CIRCUIT
For use where there is preference as to direction of traffic.

after the check lock lever at A has been thrown to the full reverse position, and, after having been moved from its normal position, the lever at A can be returned to the full normal position only after the return of the check lock lever at Z to full normal. Thus it will be seen that it is impossible to have a condition existing which would permit signal levers No. 1 and No. 20 to be reversed at the same time.

The final movement of the check lock lever at Z in being moved to the full reverse position, and of the check lock lever at A in being placed normal, is permitted by energy secured from the battery located at the far end of the circuit.

of either lever in moving to the reverse position is effected by current taken from the battery at the far end of the circuit.

The check locking circuit shown in Fig. 104 is designed for operation when there is a preference in the direction of traffic. Here traffic movements can normally be made from A to Z without any interference from the check locking, it being necessary, however, when making a movement from Z to A (against traffic) to operate both check lock levers.

Each station is equipped with a check lock lever so interlocked with signal levers No. 1 and No. 20 that lever No. 1 is free to be moved only when the check lock lever at A is full normal, and lever No. 20 only when the check lock lever at Z is full reverse. The control, however, of the check lock levers is such that the lever at Z can be reversed only

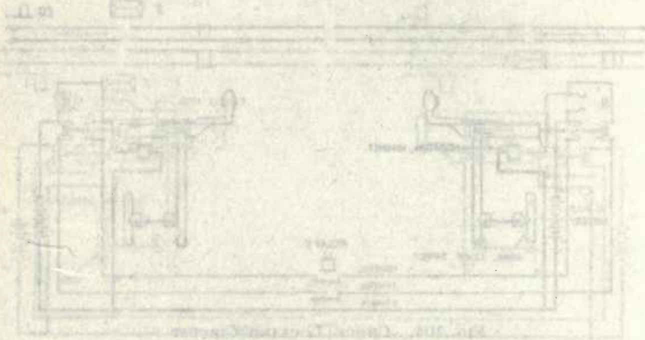


Fig. 104. Check Locking Circuit.
For use where there is preference as to direction of traffic.

after the check lock lever at A has been thrown to the full reverse position, and, after having been moved from its normal position, the lever at A can be returned to the full normal position only after the return of the check lock lever at Z to full normal. Thus it will be seen that it is impossible to have a condition existing which would permit signal levers No. 1 and No. 20 to be reversed at the same time.

The final movement of the check lock lever at Z in being moved to the full reverse position, and of the check lock lever at A in being moved normal is permitted by energy secured from the battery located at the far end of the circuit.

SECTION VI

INSTALLATION AND OPERATING DATA FOR POWER PLANTS AND SWITCHBOARDS

COVERING LEAD TYPE STORAGE BATTERIES, GENERATORS AND MOTOR GENERATORS, GASOLINE ENGINES AND SWITCHBOARDS, WITH DATA AND TABLES FOR THE DETERMINATION OF THE PROPER TYPE AND CAPACITIES OF APPARATUS

LEAD TYPE STORAGE BATTERIES

STORAGE or secondary batteries consist of cells, the plates and electrolyte of which can be restored to their original condition after discharge, by forcing an electric current through the cell in the direction opposite to that taken by the current produced by the cell. When a primary battery is exhausted the electrolyte and elements are renewed before further use. It is in this reversability or regeneration that lies the fundamental difference between storage and primary cells.

The lead type storage cell consists essentially of two plates or sets of plates suspended in a dilute solution of sulphuric acid. There are many forms of plate construction, but the chemical composition is generally the same, the positive and negative plates being made of peroxide of lead and pure

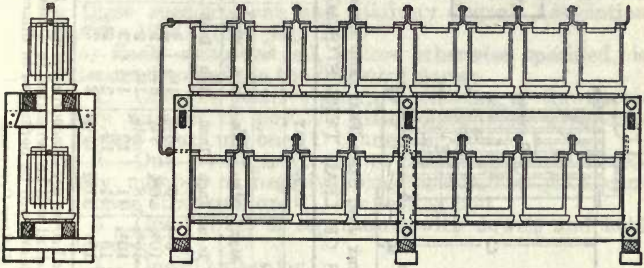


Fig. 105 Lead Type Storage Battery and Battery Rack

or "sponge" lead, respectively. When the elements are composed of more than two plates the negative plates in each cell are one more in number than the positives. Wooden or hard rubber separators are introduced between the plates to prevent any of the positives from coming into contact with the negative plates, thus causing short circuit.

When the circuit is closed and the battery discharging, the sulphuric acid combines with the lead in the elements forming a deposit of sulphate of lead on the surface of both positive and negative plates, the density (specific gravity) of the electrolyte diminishing as the sulphuric acid leaves it to combine with the materials of the plates. By forcing current through the cell in the direction opposite to that of the discharged current, the sulphate of lead on the negative plates will be converted into sponge lead and sulphuric acid, and the sulphate of lead in the positive plates into peroxide of lead and sulphuric acid; the sponge lead and the peroxide of lead remain in the plates and the sulphuric acid diffuses in the electrolyte, the specific gravity of which rises in consequence.

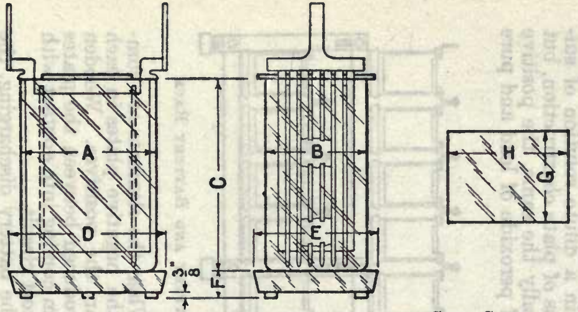


FIG. 106. BATTERY JAR, SAND TRAY AND CELL COVER

DIMENSIONS AND WEIGHTS OF LEAD TYPE STORAGE BATTERY CELLS

Capacity of Battery	Normal Charging Current at 8-Hour Rate	Number of Plates per Cell	Battery Jar A	Battery Jar B	Battery Jar C	Sand Tray D Min.	Sand Tray D Max.	Sand Tray E Min.	Sand Tray E Max.	Sand Tray F Min.	Sand Tray F Max.	Cell Cover G	Cell Cover H	Approx. Installation Height	Approx. Weight of Cell Comp.	Approx. Weight of Electrolyte
Amp. Hr.	Amps.		Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Lbs.	Lbs.
40	5	5	7⅞	4¼	11	9	9½	6	6½	1½	2	3⅞	6	17	37.56	10.75
80	10	5	9⅛	5½	12¼	10¼	10¾	6¾	7¼	1½	2	6 1/16	6¼	19½	63.65	18.75
120	15	7	9⅛	6¼	12¼	10¼	10¾	8	8½	1½	2	6 1/16	8	19½	80.25	22.00
200	25	11	9⅛	9⅛	12¼	10¼	10¾	11	12	1½	2	6 1/16	10¼	19½	112.16	27.25
320	40	9	12⅝	9	17	14	15	11	12	2	2½	8 1/16	10¾	24¼	189.86	55.00
400	50	11	12⅝	10⅝	17	14	15	11½	12½	2	2½	8 1/16	11¾	24¼	217.61	59.75

NOTE.—Dimensions of battery jar, sand tray, and cell cover are in accordance with R. S. A. Plan, No. 1224, dated October, 1912.
A variation of one-eighth inch each way from standard will be permitted in dimension "A."
A variation of one-fourth inch each way from standard will be permitted in dimensions "B" and "C."

Weights in above table furnished by Electric Storage Battery Company.

EXTRACT FROM R. S. A. SPECIFICATIONS FOR LEAD TYPE STATIONARY STORAGE BATTERY FOR INTERLOCKINGS (1913)

1. Intent

The intent of these specifications is to provide for the furnishing of complete storage battery cells and parts, designed to be located in interlocking stations or battery houses and used for operating interlocking and signal apparatus.

2. Designations

(*a*) In ordering cells or parts the nominal capacity required will be designated as "40 A. H., "80 A. H.," "120 A. H.," "200 A. H.," "320 A. H.," or "400 A. H.," and these terms shall be understood to signify, on an eight (8) hour basis, the capacities and dimensions thus designated in these specifications and Railway Signal Association drawing 1224. (See page 146.)

(*b*) Each complete cell, unless otherwise specified, is understood to include the following parts:

1. One (1) positive group, consisting of the necessary number of positive plates assembled with connecting strap and one (1) connecting bolt.
2. One (1) negative group, consisting of the necessary number of negative plates assembled with connecting strap and one (1) connecting bolt.
3. One (1) set of separators, with dowels and hold downs.
4. One (1) glass jar.
5. One (1) glass sand tray, with moulded feet.
6. One (1) glass cell cover.
7. Required electrolyte.

(*c*) Positive or negative groups, if ordered separately, will be ready for service after an initial charge continued for fifty (50) to sixty (60) hours at the eight (8) hour rate.

3. Capacity of Battery

In conformity with service requirements.

4. Number of Cells per Battery

In conformity with voltage requirements.

5. Dimensions

Jars, sand trays and covers must conform to Railway Signal Association drawing 1224, which is an essential part of these specifications. (See page 146.)

6. Elements

(*a*) Positive plates shall be of the Plante type.

(*b*) Negative plates shall be either of the Plante type or of the type having mechanically applied active material.

(*c*) Positive and negative plates shall be respectively connected into positive and negative groups by burning to lead straps.

7. SEPARATORS

Separators shall be of specially treated wood.

8. ELECTROLYTE

(*a*) Electrolyte shall have a specific gravity of between 1.205 and 1.215 at the end of the initial charge in service.

(*b*) Electrolyte shall be in accordance with Railway Signal Association specifications.

9. ACCEPTANCE

No unit or part will be accepted which does not, in the judgment of the Purchaser, conform to the best practice with respect to material and workmanship.

10. SERVICE REQUIREMENTS

(*a*) It is essential that all parts shall be rugged in the highest degree both mechanically and electrically. The apparatus furnished must give satisfactory and economical service.

(*b*) Should any injurious buckling of plates occur in normal service within one (1) year after delivery, or should the capacity of any cell or element fall to less than eighty-five (85) per cent. of the specified capacity at the eight (8) A. H. rate, in normal service, within one (1) year after delivery, the Contractor must replace the defective parts and restore the affected cells to their full specified capacity and to a condition satisfactory to the Purchaser, without additional cost to him.

(*c*) As far as practicable, it is understood that the cells are to be operated in the manner recommended by the Contractor, but the necessities of operation must be the first consideration.

R. S. A. DIRECTIONS FOR INSTALLATION OF LEAD TYPE STATIONARY STORAGE BATTERIES (1909)

1. GENERAL

(*a*) The battery should be housed in a space by itself as the acid fumes given off during the charge are of a corrosive nature. This space should be well ventilated, well lighted, and as dry as possible. If the space is specially constructed it should contain no metal work other than lead. If this is not possible, then such metal parts should be protected by at least two (2) coats of acid-proof paint. The floors of a large battery room should be preferably of vitrified brick, jointed with pitch.

(*b*) Batteries should be placed in a room having a uniform temperature, preferably seventy (70) degrees Fahr. Low temperature does not injure a battery, but lowers its capacity approximately one-half (½) of one per cent. per degree. Excessively high temperatures shorten the life of the plates.

(*c*) If glass jars are used and cell is not of the two-plate type, the following should be observed:

1. Batteries up to four hundred (400) ampere hour capacity shall be placed in glass jars.
2. The capacity of batteries shall be for an eight (8) hour rate of discharge at seventy (70) degrees Fahr.
3. Batteries having a large number of cells, such as at interlocking plants, shall be provided with substantial wood racks to support them. These racks shall preferably be made of long-leaf yellow pine with non-corrosive fastenings, and thoroughly protected by at least two (2) coats of acid-proof paint. Cells shall be arranged transversely, and the layouts be such that each cell is accessible for inspection and provide sufficient head room over each cell to remove the element without moving the jar.
4. Each jar shall be set in a tray which has been evenly filled with fine dry bar sand, the trays resting on suitable insulators.
5. When placing the positive and negative groups into the jars see that the direction of the lug is relatively the same in each case, so that a positive lug of one (1) cell adjoins and is connected to a negative lug of the next cell throughout the battery, thereby giving proper polarity, providing a positive lug at one free end and a negative at the other.
6. Before bolting the battery lugs together, they should be well scraped at the point of contact, to insure good conductivity and low resistance in the circuit. The connector studs should be covered with vaseline before screwing up, and all connections covered with vaseline or suitable paint.
7. Before putting electrolyte in the battery the circuits connecting same with the charging source must be completed, care being taken to have the positive pole of the charging source connected with the positive end of the battery and the negative poles. The electrolyte should cover the top of plates by one-half (½) inch.

2. ELECTROLYTE

(*a*) The electrolyte must be free from impurities and meet the tests prescribed by the Railway Signal Association.

3. Initial Charge

(*a*) The initial charge must follow the Manufacturer's instructions. The charge should be started promptly as soon as all the cells are filled with electrolyte, and all connections made, usually at the normal rate, and continued at the same rate until both the specific gravity and voltage show no rise over a period of ten (10) hours, and gas is being freely given off from all the plates. The positive plates will sometimes gas before the negatives. Generally, to meet these conditions, from forty-five (45) to fifty-five (55) hours continuous charging at the normal rate will be required; and if the rate is less, the time required will be proportionately increased. In case the charge is interrupted, particularly during its earlier stages, or if it is not started as soon as the electrolyte is in the cells, the total charge required (in ampere hours) will be greater than if the charge is continued and is started at once.

(*b*) As a guide in following the progress of the charge, readings should be regularly taken and recorded. The gassing should also be watched, and if any cells are not gassing as much as the adjoining cells, they should be carefully examined and the cause of the trouble removed. The temperature of the electrolyte should be closely watched, and if it approaches one hundred (100) degrees Fahr. the charging rate must be reduced or the charge temporarily stopped until the temperature lowers.

(*c*) The specific gravity will fall after the electrolyte is added to the cells, and will then gradually rise as the charge progresses, until it is up to 1.210 or thereabout.

(*d*) The voltage of each cell at the end of the charge will have risen to its maximum and usually will be between two and five-tenths (2.5) and two and seven-tenths (2.7) volts.

(*e*) If the specific gravity of any of the cells at the completion of the charge is below 1.205, or above 1.215, allowance being made for the temperature correction, it should be adjusted to within these limits, by removing and adding electrolyte if the specific gravity is low, and adding chemically pure water if the specific gravity is high, to again bring the surface at the proper height above the top of the plates. It is of the utmost importance that the initial charge be complete in every respect.

(*f*) In case of batteries charging from primary cells, if possible, the initial charge should be given at a place where direct current is available of sufficient voltage to complete the charge at the normal rate, the cells being then transferred to their permanent position.

4. Two-plate Cells

The general method of installation is the same as the above with the following exceptions: Each cell contains one positive and one negative plate, the positive of one cell being solidly connected by a lead strap to the negative plate of the adjoining cell, and consequently no connectors are required. At the ends of each row there is one (1) free positive plate and one (1) free negative plate respectively, which constitute the positive and negative terminals of that row. Connections to these terminals are made with bolt connectors.

5. LARGE CAPACITY CELLS

(*a*) Batteries of a greater capacity than four hundred (400) ampere hours shall be placed in wood tanks and shall be covered by special specifications.

(*b*) Where tanks are used, it is customary to support them on a double tier of glass insulators.

(*c*) Plates are shipped separately and assembled one at a time in the tank and burned solidly to a heavy lead bus bar by means of a hydrogen flame. It is recommended that when installations of this kind are required that battery Manufacturers install the battery in accordance with their standard practice.

R. S. A. INSTRUCTIONS FOR OPERATION OF LEAD TYPE STORAGE BATTERIES AT INTERLOCKING PLANTS (1909)

1. BATTERY

.....batteries;.....cells each; type......; number of plates per cell......normal charging rate......amperes.

.....batteries;.....cells each; type......; number of plates per cell......normal charging rate......amperes.

2. PILOT CELL

In each battery, select a readily accessible cell, to be used in following the daily operation of the battery, by taking specific gravity readings of the electrolyte, as given below. Keep the level of the electrolyte of this cell at a fixed height, one-half (½) inch above the top of the plates, by adding a small quantity of chemically pure water each day; THIS IS EXTREMELY IMPORTANT.

3. CHARGING

(*a*) *When to charge.*

1. As a general rule, do not charge until the specific gravity of the pilot cell has fallen at least ten (10) points below the preceding overcharge maximum, the battery being then about one-third (⅓) discharged.

2. In any case, charge as soon as possible after reaching either of the limits given below under "Discharging," or if for any reason a heavy discharge is expected.

(b) *Regular charge.*

1. Charge at normal rate of ....amperes, or as near as possible, and continue until the specific gravity of the pilot cell has risen to three (3) points below the maximum reached on the preceding overcharge, WHEN THE CHARGE SHOULD BE STOPPED: for example, if the maximum specific gravity on the overcharge is 1.207, the specific gravity reached on regular charge should be 1.204.

2. The cells should all be gassing moderately.

(c) *Overcharge.*

1. Once every two (2) weeks, on................ prolong the regular charge until fifteen (15) minute readings of the specific gravity of the pilot cell and of the battery voltage, taken from the time the cells commence to gas show no rise on five (5) successive readings, thus having been at a maximum for one hour.

2. When the above method of overcharge is not practicable, the overcharge may be given every sixth charge, provided the battery receives an overcharge at least once every month. If in following this method, i. e., where the overcharge is given at intervals longer than two (2) weeks and not less frequently than once a month, the regular charge should be prolonged until one-half (½) hour readings of the specific gravity of the pilot cell and of the battery voltage, taken from the time the cells begin to gas, show no rise on seven (7) successive readings, thus having been at the maximum for three (3) hours.

3. The cells should all be gassing freely.

4. The overcharge should be given whether the battery has been in regular use or not.

(d) *Charging in series.*

If two (2) or more batteries are charged together, in series, care should be taken that each battery is cut out when fully charged; in other words, if one of the batteries discharges less than the other it should not receive the same charge.

4. DISCHARGING

(a) Never allow the specific gravity of the pilot cell to fall more than about thirty (30) points below the preceding overcharge maximum. As a rule, do not allow specific gravity to fall more than twenty (20) points.

(b) Never allow the voltage to go below ONE AND EIGHTY-FIVE ONE-HUNDREDTHS (1.85) VOLTS PER CELL when discharging at the normal rate (..........amperes). If the rate of discharge is less than the normal rate, the voltage should not be allowed to go so low.

Limiting voltage..........cells..........volts.
Limiting voltage..........cells..........volts.

(c) Never allow the battery to stand in a *completely discharged* condition.

5. READINGS

(*a*) Read and record the specific gravity of the pilot cell and battery voltage just before starting and ending every charge, together with the temperature of the electrolyte.

(*b*) To properly compare the specific gravity readings, they should be corrected to standard temperature (seventy (70) degrees Fahr.) by adding one (1) point for every three (3) degrees above, and subtracting one (1) point for every three (3) degrees below standard temperature.

(*c*) Once every two (2) weeks, after the end of the charge preceding the overcharge, read and record the gravity of each cell in the battery.

6. INSPECTION

(*a*) Carefully inspect each cell on the day before the overcharge, using a lamp on an extension cord for the purpose. Examine between the plates and hanging lugs to make sure that they are not touching, and also make a careful note of any peculiarity in color, etc., of the plates.

(*b*) Use a strip of wood or hard rubber in removing short circuits. NEVER USE METAL.

(*c*) Toward end of the charge preceding the overcharge, note any irregularity of gassing; cells gassing slowly should be investigated.

7. INDICATIONS OF TROUBLE

(*a*) FALLING OFF IN SPECIFIC GRAVITY OR VOLTAGE relative to the rest of the cells.

(*b*) LACK OF OR SLOWER GASSING on overcharge, as compared with adjoining cells.

(*c*) COLOR OF PLATES markedly lighter or darker than in adjoining cells, except that sides of plates facing glass may vary considerably.

(*d*) In case of any of the above symptoms being found, examine carefully for cause, and REMOVE AT ONCE.

(*e*) Report trouble of any description at once to.......
....

8. BROKEN JARS

If a jar should break, and there is no other to take its place, so that the plates will have to remain out of service for some time, keep the negatives covered with water and allow the positives to dry. Connect into circuit again just before a charge, so that the plates will receive the benefit of the charge.

9. OTHER IMPORTANT POINTS

(*a*) Plates must always be kept COVERED WITH ELECTROLYTE.

(*b*) Use only CHEMICALLY PURE WATER, preferably distilled, to replace evaporation.

(*c*) NEVER ADD ELECTROLYTE EXCEPT under the conditions explained above.

(*d*) Never allow the SEDIMENT to get to the bottom of the plates; remove sediment when the clearance has reached one-half (½) inch.

(*e*) VENTILATE the room freely, especially when charging.

(*f*) Never bring an EXPOSED FLAME near the battery when charging.

(*g*) NEVER ALLOW METALS OR IMPURITIES of any kind to get into the cells; if this happens, remove and wash the plates and renew the electrolyte.

(*h*) Fill out the report sheets regularly.

(*i*) READ THE GENERAL INSTRUCTIONS CAREFULLY.

REQUIRED CAPACITY OF STORAGE BATTERIES USED WITH G. R. S. ELECTRIC INTERLOCKING

A storage battery of fifty-five to fifty-seven cells, having an approximate potential of 110 volts, is used in connection with G. R. S. electric interlocking installations. The required ampere hour capacity is dependent on a number of variables, viz: the number of days between charges, frequency of lever movements, amount of current required for lighting, for cut-outs, indicators, annunciators, etc., and the number of days of reserve power desired.

A separate low voltage battery is generally installed when there are a number of locks, indicators, relays, etc., required at the plant, as this type of device is more efficient and can have a more rugged magnet winding when designed for operation on a potential of 10 or 20 volts; furthermore, there are certain safety features which can be secured in connection with this low voltage control. The capacity of such a low voltage battery is determined in the same manner as the high voltage battery, as given hereafter.

The following instructions will enable the determination, with reasonable accuracy, of the ampere hour capacity of the battery required for use with a G. R. S. electric interlocking plant.

AMPERE HOUR CAPACITY REQUIRED FOR OPERATION OF FUNCTIONS (See also table on page 158.)

The ampere hour capacity required for the operation of functions is obtained by multiplying the number of lever movements per day by the number of days between charges and by a "Function Constant." This constant, to be obtained by reference to table on page 155, is influenced mainly by two things: the average length of time that signals are held in the proceed position and the ratio of the number of signal movements to switch movements. In the absence of definite information on these points it is suggested that the constant .006 be used as representing a fair average condition. This constant is shown underlined in the table.

By reference to the table of Function Constants it can be easily seen that it is advisable to keep down the length of time signals are held in the proceed position, a glance indicating that the battery capacity will run up very rapidly as the time of holding signals at proceed increases. In this connection it may be stated that there have been cases where a much smaller size battery has been permitted due to the saving in

TABLE OF FUNCTION CONSTANTS

Average Length of Time Signals are Held in Proceed Position Minutes	Ratio of Signal to Switch Movements 1–2	1–3	1–4	1–5
2	.006	.005	.005	.005
3	.007	.006	.006	.006
5	.010	.008	.007	.007
10	.016	.013	.011	.010
15	.022	.017	.015	.013
30	.041	.032	.026	.023

hold clear current, this being effected by the installation of annunciators, which by suitably indicating the approach of a train reduces the length of time of holding the signals at proceed. Furthermore, it is interesting to note that the saving effected by the installation of this smaller battery may more than balance the cost of such annunciator installation.

Ampere Hours Required for Operating Switchboard Cut-Outs

In every G. R. S. electric interlocking plant one or more circuit breaker cut-outs are required for cross protection purposes. The capacity required for cut-outs is obtained by multiplying the number of cut-outs by nine-tenths and by the number of days between charges. A discussion as to the number of cut-outs to be employed to suitably sectionalize a plant is given on page 93.

Ampere Hours Required for Electric Lighting
(See page 127.)

When the signals at an interlocking plant are to be lighted by electricity, the interlocking battery is generally held as a reserve against the failure of the normal source of power. The number of days which the battery may be called upon to furnish current in such an event depends upon the probable length of time required to repair any derangement of the apparatus normally furnishing power to the lighting system. The ampere hour capacity which must be provided for the lighting is, therefore, determined by multiplying the ampere hours per signal per day by the number of signals to be lighted and the number of days' operation which may be required between charging periods.

TABLE OF AMPERE HOURS PER DAY PER SIGNAL. 110 VOLT CARBON FILAMENT BULBS — TWO BULBS PER SIGNAL, CONNECTED IN MULTIPLE

Candle Power per Bulb	Average Number of Hours Lights are Burned per Day		
	12	13	14
	Ampere Hours	Ampere Hours	Ampere Hours
2	2.18	2.36	2.55
4	4.36	4.72	5.09

NOTE.—Values approximate.

Ampere Hours Required for Miscellaneous Purposes

When auxiliary devices, such as indicators, locks, etc., are operated from the interlocking battery, the current taken for this purpose must be included in figuring the capacity of the battery. The current required by these devices can be secured by reference to tables on pages 265 to 269. The capacity of battery required for this purpose is obtained by multiplying the current taken by said auxiliary devices by the average number of hours such apparatus is energized per day, and by the number of days between charges.

Reserve Ampere Hours

Under normal operating conditions the battery should not be fully discharged on account of the fact that charging current may not be always instantly available when wanted, in which case the time would surely come when the plant would be without means of operation. It is, therefore, necessary to have the battery of such size that at the usual time of charging there will be a certain number of ampere hours capacity left in the battery as a reserve.

The R. S. A. recommends that under normal conditions the battery never be discharged beyond two-thirds of its total capacity; stated in other words, this means that 50 per cent. must be added to the capacity computed when installing the battery in accordance with R. S. A. specifications. If the battery is to be charged at intervals of a week this will give a reserve of three and one-half days, and if at intervals of two weeks the reserve will be for seven days. When a commercial source of power is available, this in all probability will give more reserve than would be necessary. On the other hand, if the charging source is not so reliable, the capacity of the battery may have to be increased. For instance, the charging of the batteries at an isolated plant may be dependent upon a gasoline engine, the failure of which might take several days for repairs due to time spent in securing repair parts, etc. In such a case when the charging is done at intervals of a week, it would, perhaps, be necessary to have a reserve sufficient for a full week's operation, this requiring that the computed capacity of the battery be increased by 100 per cent.

Based on the above, it is recommended as good practice that the battery provide for a minimum reserve of 50 per cent. and that, if local conditions require it, an additional amount of reserve be added as outlined above.

Method of Tabulation

When determining the capacity of a battery the different items may be tabulated as shown below; in which—

- L stands for "lever movements per day."
- C stands for "function constant."
- D stands for "days operated between charges."
- N stands for "number of units operated."
- AH stands for "ampere hours per day per signal."
- A stands for "amperes."
- H stands for "hours energized per day."

Functions	L x C x D	= ...... ampere hours
Cut-Outs	$\frac{9}{10}$ x H x D	= ...... ampere hours
Lighting Signals	AH x N x D	= ...... ampere hours
Auxiliary Apparatus	A x H x N x D	= ...... ampere hours
Total of above		= ...... ampere hours
Reserve to be added		= ...... ampere hours
Total capacity of Battery		= ...... ampere hours

When the Number of Lever Movements is Not Known

When it is not possible to ascertain the number of lever movements to be made in a given plant, the ampere hour capacity of battery required for the operation of functions and for cut-outs can be secured from the following table; these figures include sufficient reserve to care for ordinary conditions.

TABLE GIVING BATTERY CAPACITY FOR OPERATION OF FUNCTIONS AND CUT-OUTS

Size of Machine	Size of Battery
8 to 16 levers	40 ampere hour battery
16 to 32 levers	60 ampere hour battery
32 to 48 levers	80 ampere hour battery
48 to 88 levers	120 ampere hour battery
88 to 128 levers	160 ampere hour battery
128 to 168 levers	200 ampere hour battery

The table is based on past experience and is considered reasonably correct for moderate size machines, the battery sizes, if anything, being somewhat high. The table is not extended for machines larger than 168 levers, as with such plants it is believed that special study of lever movements should be made in the determination of the battery size.

If the signals are to be lighted and auxiliary apparatus operated from the interlocking battery, an additional number of ampere hours must be added to the figures in the table, the calculation being made in accordance with the preceding paragraphs dealing with the capacity required for electric lighting and for miscellaneous purposes.

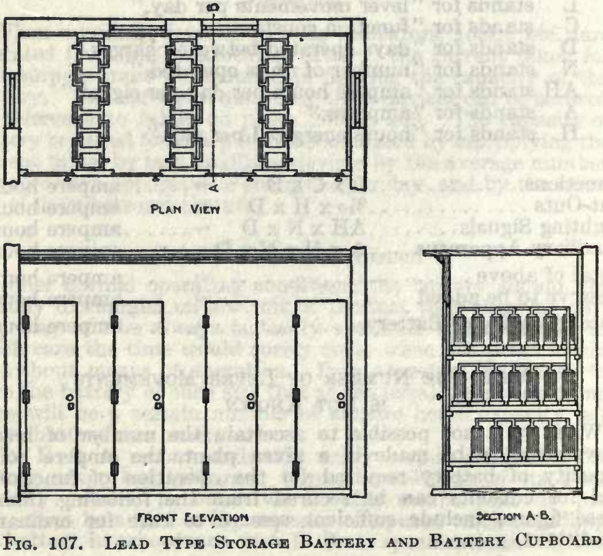


Fig. 107. Lead Type Storage Battery and Battery Cupboard

GENERAL DATA ON CHARGING LEAD TYPE STORAGE BATTERIES

Capacity of Battery	Normal Charging Current at 8-Hour Rate	Required Generator Capacity at 160 V. Max.	Required H. P. for Belt-Connected Gas Engine	DC-DC Motor-Gen. Sets		AC-DC Motor-Gen. Sets		Mercury Arc Rectifier
				Input	Floor Space Required	Input	Floor Space Required	Input
Amp. Hrs.	Amps.	K W	H. P.	K W	Inches	K W	Inches	K W
40	5	1.00	1.50	1.25	45 x 18	1.50	39 x 18	1.00
60	7.5	1.25	2.25	1.75	47 x 19	2.00	41 x 19	1.50
80	10	1.75	3.00	2.50	49 x 21	2.75	43 x 20	2.00
120	15	2.50	4.25	3.25	52 x 23	3.75	46 x 22	3.00
160	20	3.25	5.75	4.25	55 x 24	5.00	49 x 23	4.00
200	25	4.00	7.00	5.50	58 x 26	6.25	51 x 25	5.00
240	30	4.75	8.50	6.00	60 x 28	7.00	54 x 26	6.00
280	35	5.75	10.00	7.00	63 x 30	8.00	56 x 28	7.00
320	40	6.50	11.25	8.00	66 x 31	9.25	58 x 29	8.00
400	50	8.00	14.00	10.00	70 x 33	11.50	60 x 31	10.00

NOTE.— The above recommendations for required H. P. of gas engines is based on R. S. A. specifications.
The data on inputs and floor space is closely approximate and is satisfactory for estimating purposes.
Motors for DC-DC Motor generator sets designed for operation on 110, 220, 440, or 550 volts direct current.

Motors for AC-DC Motor generator sets assumed to operate on 25 or 60 cycle single phase current. Efficiencies for two and three phase sets of equal capacities are closely the same; dimensions, however, are somewhat less than those shown.

When Mercury Arc Rectifiers are used on 60 cycle circuit, 220 volts only AC is necessary to give required amperes at 160 volts. When used on 25 cycle circuit, 440 volts AC is required—this generally means that a transformer must be installed, as 440 volts 25 cycle current is not a commercial standard.

G. R. S. BATTERY CHARGING SWITCH

The battery charging switch illustrated by Fig. 108 provides a simple and efficient means for connecting storage batteries in series with charging and discharge lines, permitting the batteries to be switched off or on to the line without opening the charging circuit.

During the manipulation of the switch, short circuiting of the battery is avoided by automatically inserting a resistance during the interval that the battery would otherwise be on short circuit, which resistance is again cut out as soon as that point is passed.

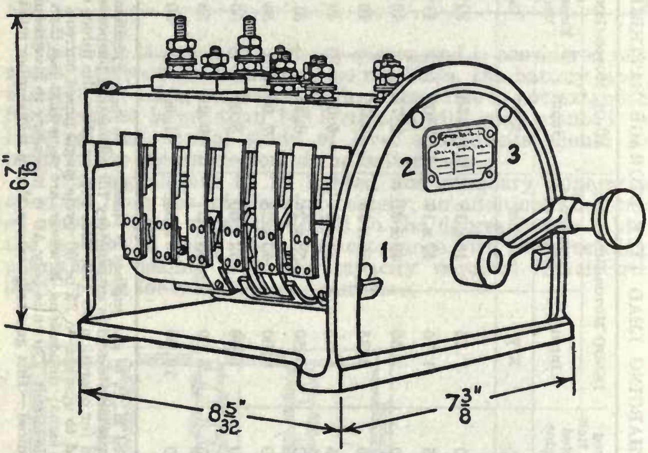
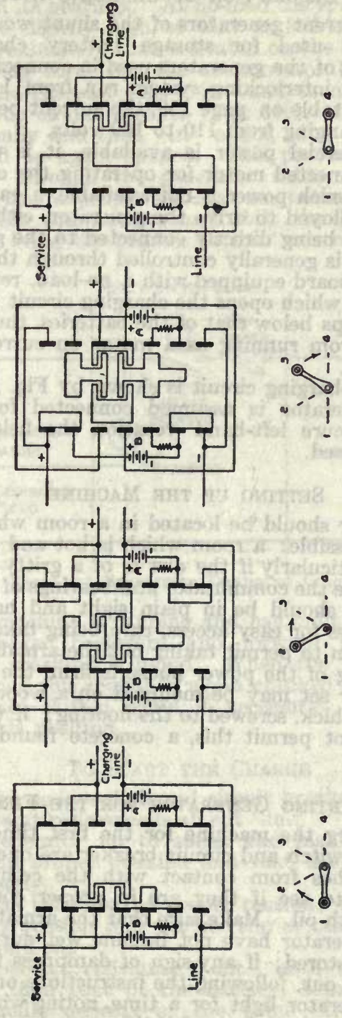


Fig. 108. Battery Charging Switch

Manipulation of the switch is simple, the four different positions of the switch controlling the battery as follows:

1 — Battery A discharging, Battery B charging.
2 — Battery A discharging, Battery B open.
3 — Battery B discharging, Battery A open.
4 — Battery B discharging, Battery A charging.

The charging switch is compact and substantial in design and so arranged to permit of easy inspection. The commutator possesses a high degree of insulation. The contact plates and fingers are large, being designed to take care of the heavy currents necessary in this kind of work without heating.



Battery A Discharging.
Battery B Charging.

Battery A Discharging.
Battery B Open.

Battery B Discharging.
Battery A Open.

Battery B Discharging.
Battery A Charging.

FIG. 109. DIAGRAM OF CONNECTIONS MADE AT THE DIFFERENT OPERATING POSITIONS OF THE BATTERY CHARGING SWITCH

DIRECT CURRENT GENERATORS

General Description of Charging Apparatus

DIRECT current generators of the shunt wound type are ordinarily used for storage battery charging. The capacities of the generators used in connection with the G. R. S. electric interlocking system run from 1 to 8 K. W., as shown in the table on page 159, the current being delivered at a potential ranging from 110 to 160 volts.

Where commercial power is available, it is preferable to use a direct connected motor for operating the charging generator. Where such power is not available, a gasoline engine is generally employed to drive the generator, either by means of belting or by being directly connected to the generator.

The charging is generally controlled through the medium of a power switchboard equipped with a no-load, reverse-current circuit breaker, which opens the charging circuit if the generator voltage drops below that of the batteries, thus preventing the generator from running as a motor on current delivered by the batteries.

A simplified charging circuit is shown by Fig. 110. In this circuit the generator is assumed connected for right-hand rotation; to secure left-hand rotation the field connection should be reversed.

Setting up the Machine

The generator should be located in a room which is as dry and clean as possible: a room which is hot and dusty should be avoided, particularly if the dirt is of a gritty character, as it is apt to injure the commutator and bearings of the machine.

The machine should be in plain sight and have sufficient room on all sides for easy access, care being taken that there is sufficient room to permit taking out the armature.

If the flooring of the power house is firm, the generator or motor generator set may be mounted on a wood block three or four inches thick, screwed to the flooring; if the floor construction will not permit this, a concrete foundation should be installed.

When Starting Generator for the First Time

Before starting the machine for the first time, make sure that the main switch and circuit breaker are open (Fig. 110). Raise the brushes from contact with the commutator and examine them to see if they are in proper condition. Fill the bearings with oil. Make sure that the armature and field coils of the generator have not become wet during shipment or while being stored; if any sign of dampness is noted they should be dried out, following the instructions on page 165.

Run the generator light for a time, noting whether the oil rings are working properly, and if the generator is belt driven, note whether the machine is so lined up that the belt runs central on the pulleys and the armature plays freely back and forth between its bearings. At no-load the speed of the generator should be slightly high, so that at full-load it will come down to approximately that indicated on the name plate.

After making sure that the commutator brushes are still raised, cut the rheostat fully "in" and then close the main switch and the circuit breaker (Fig. 110). Cut the rheostat "out" gradually and then "in" again, after which the main switch should be again opened. This procedure causes current to flow through the generator fields and insures the field coils having a proper residual magnetism. Replace the brushes on the commutator and shift the brush holder, if necessary, to bring the brushes to the "neutral" position.

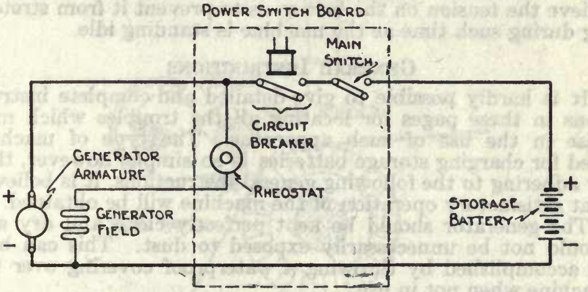


Fig. 110. Simplified Charging Circuit

After the machine is running and has built up, the brushes should be rocked backward and forward until the point of minimum sparking is found. When the machine is running under load this should be again checked and the position of the brushes shifted again if necessary; lock and leave brushes in this position.

To Start the Charge

See that the main switch and circuit breaker are open, and that the rheostat resistance is all cut "in."

Get the generator up to speed and make sure that the brushes are in proper position and that the oiling rings are working properly.

See that the belt has the proper tension; that is, it should be as loose as possible and yet not slip or tend to run off the pulley with load on.

Cut the rheostat resistance "out" until the voltage is a little higher than that of the battery, being sure that the voltmeter needle deflects in the same direction for both generator and battery (see switch No. 2, Fig. 118). This latter insures that the positive terminal of the generator will be connected to the positive pole of the battery.

Close the main switch and circuit breaker and adjust the rheostat until the proper amount of current is flowing into the battery, also adjust the brushes if necessary for minimum sparking. It will be necessary to change the adjustment of the rheostat occasionally as the battery charging increases, in order to maintain the current at the proper amount.

To Shut Down

To shut down, lower the voltage by cutting "in" the rheostat until the circuit breaker on the switchboard opens of itself and then stop the engine. If no circuit breaker is provided, wait until the current is practically at zero before opening the main switch on the battery. After the machine has stopped, relieve the tension on the belt so as to prevent it from stretching during such time as the machine is standing idle.

General Instructions

It is hardly possible to give detailed and complete instructions in these pages for locating all the troubles which may arise in the use of such apparatus. The type of machine used for charging storage batteries is so simple, however, that by adhering to the following general instructions, it is believed that satisfactory operation of the machine will be obtained.

The generator should be kept perfectly clean and dry and should not be unnecessarily exposed to dust. This can best be accomplished by throwing a waterproof covering over the machine when not in use.

Do not overload the machine. To load the machine beyond the capacity indicated on its name-plate is never conducive to best operation, this being the frequent cause of overheating in the machine, sparking at the commutator, or other troubles.

Overheating the generator may be readily detected by applying the hand to the various parts of the machine; in general a temperature that cannot be borne by the hand is to be considered excessive. An odor of burning varnish is indicative of serious overheating, and a machine which shows this symptom should have the load removed at once; rotation of the armature may be continued with the fields de-energized for the purpose of cooling the machine.

The bearings should be kept thoroughly lubricated with the best grade of lubricating oil. While the machine is running, care should be taken from time to time to see that the oiling rings are working correctly.

Particular attention should be given to the commutator and brushes to see that the former keeps perfectly smooth and that the latter are in perfect adjustment. The commutator should assume a dark brown, glossy appearance, if proper brushes are used and are kept from sparking, and if the capacity of the machine as indicated on the name plate is not exceeded. The condition of the commutator and brushes may be regarded as the best barometer of the condition of the generator.

The free use of lubricants on the commutator is not recommended. In cleaning the commutator a tightly woven cloth (free from lint) or chamois skin, should be used and the commutator then wiped with a rag which has a little vaseline on it.

To fit the brushes to the commutator draw No. 00 sandpaper under them, smooth side to the commutator, as shown in Fig. 111, the brushes to bear on the sandpaper only when

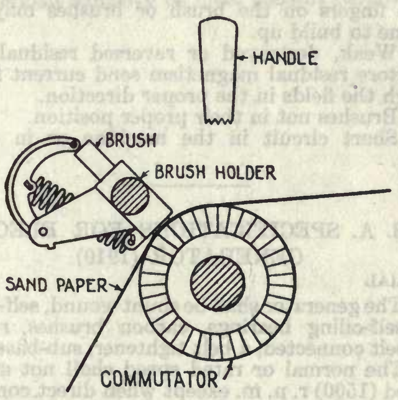


FIG. 111. METHOD OF FITTING BRUSHES TO COMMUTATOR

it is being drawn in the direction in which the surface of the commutator will run when the machine is in operation. After the brush is shaped to the commutator finish up with No. 0 sandpaper and then carefully clean the commutator and brushes of all particles of dust or grit.

The brushes shipped with the machine are ordinarily best adapted to the work and other brushes are liable to cause trouble. A little oil may be applied to the brushes should they become dry and noisy.

If the armature or field coils of the generator should become wet, they should be thoroughly dried out before running the machine under load as the moisture is liable to damage the windings. The coils of the machine may be dried out by baking in an oven at a temperature of 240 degrees Fahr. for several hours, or if an oven is not available they may be dried out by placing near the fire. Another method is to run the generator for several hours without exciting its field.

Generator Fails to Build Up

One of the common troubles which occurs in the operating of generators is the failure of the machine to build up. This failure may be generally attributed to one of the following causes:

1. Open circuit due to a broken wire, faulty connections, brushes up, fuse blown, open switch, etc.
2. Reversed connections in field circuit or reversed direction of rotation.
3. Excessive resistance due to poor brush contact. Brush contacts often have an excessively high resistance when generator is first started, and a momentary pressure of the fingers on the brush or brushes may enable the machine to build up.
4. Weak, destroyed or reversed residual magnetism. To restore residual magnetism send current from battery through the fields in the proper direction.
5. Brushes not in their proper position.
6. Short circuit in the machine or in the external circuit.

R. S. A. SPECIFICATIONS FOR ELECTRIC GENERATOR (1910)

1. Material

(*a*) The generator shall be shunt wound, self-excited, shall have self-oiling bearings, carbon brushes, rheostat, and when belt connected, a belt tightener, sub-base, and pulley.

(*b*) The normal or rated speed shall not exceed fifteen hundred (1500) r. p. m. except when direct connected to an a. c. motor or steam turbine.

(*c*) The generator shall have a continuous current capacity equal to the eight (8) hour rate (............ ampere) of the battery, at a voltage equal to the maximum voltage (............ volts) of the battery on charge, without a rise in temperature in any part exceeding seventy-two (72) degrees Fahr. (40° C.) above the temperature of the surrounding atmosphere.

(*d*) It shall be so wound that its voltage at the continuous current rating given above, may be varied by means of a field rheostat between the minimum and the maximum charging voltage of the battery.

(*e*) The generator shall be capable of supplying for four (4) hours a current output twenty-five (25) per cent. in excess of the continuous current capacity referred to in above without a rise in temperature in any part exceeding ninety (90) degrees Fahr. (50° C.) above the temperature of the surrounding atmosphere.

(*f*) It is understood that the temperature of the surrounding atmosphere is to be based on seventy-seven (77) degrees Fahr. (26° C.), but should the temperature vary from this, corrections shall be made in accordance with the recommendations of the American Institute of Electrical Engineers.

(*g*) The current output of the minimum allowable generator shall be that required for the operation of two (2) switches simultaneously.

(*h*) With the brushes in a fixed position, the generator shall be practically sparkless under all operating conditions, as outlined above.

(*i*) These generator specifications describe a machine which, in normal power interlocking service, will have an ample overload capacity to meet general requirements.

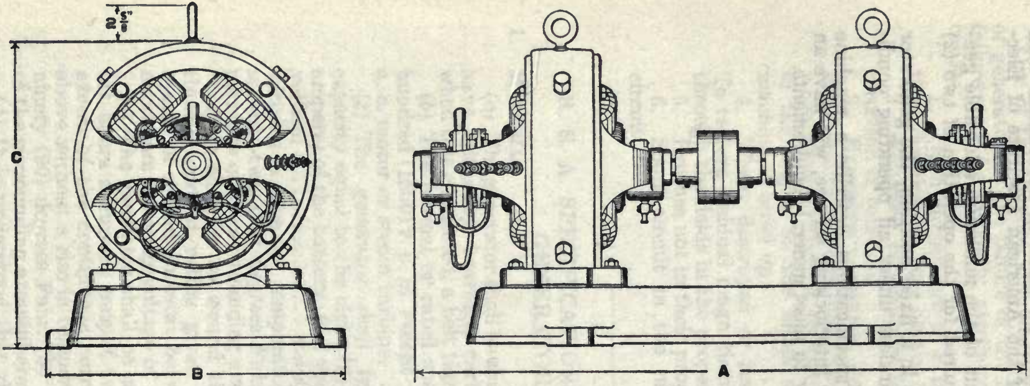


Fig. 112

INSTALLATION DATA FOR G.R.S. D.C.-D.C. MOTOR GENERATOR SETS

Maximum Capacity of Set in Kilowatts	When Used for Charging Storage Battery		Revolutions per Minute	Dimensions in Inches		
	Ampere Hour Capacity of Battery, Normal Voltage 110	Motor Generator Input at 220 Volts, (Approximate)		A (Approximate)	B	C
1.25	40	7	1500	39	21	20⅜
1.25	60	9	1500	39	21	20⅜
2.40	80	10	1500	42	21	20⅜
2.40	120	15	1500	42	21	20⅜
3.25	160	20	1500	50	21	21⅝

Note.— Motors designed for operation on voltages from 110 to 550. Amperes input at other voltages than 220 approximately in inverse proportion to voltage.

NOTE.—Gas engines shown are designed to start on gasoline and to operate on gasoline, naphtha, kerosene, or power distillate without any change of equipment.

Speed of D. C. generators — 1500 R. P. M.

Starting cranks furnished for 2, 3, and 4 H. P. gas engines only.

Data for table furnished by Fairbanks-Morse & Company.

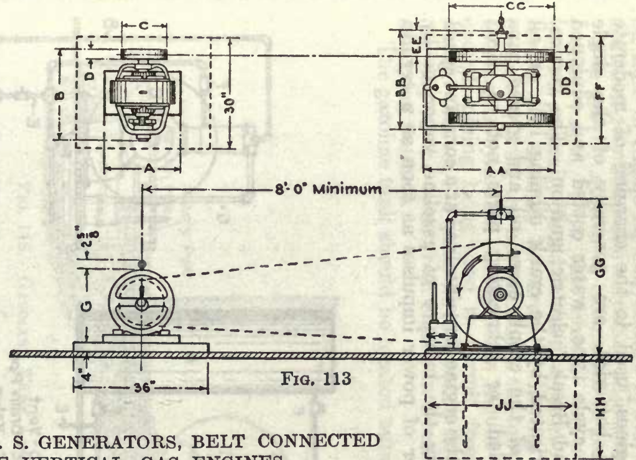


FIG. 113

INSTALLATION DATA FOR G. R. S. GENERATORS, BELT CONNECTED TO FAIRBANKS-MORSE VERTICAL GAS ENGINES

G. R. S. Co. Direct Current Generator							Fairbanks-Morse Special Electric Engine										
KW Capacity at 160 V.	Amps.	A	B	C	D	G	HP	RPM	AA	BB	CC	DD	EE	FF	GG	HH	JJ
		Inch	Inch	Inch	Inch	Inch			Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch
1.00	5	20¼	19	8½	3	18 5/16	2	450	35½	26¾	28	3¼	5½	30	41¾	36	42
1.25	7½	20¼	19	9½	3	18 5/16	3	400	42½	30	36	3¾	6	36	53⅛	42	48
1.75	10	20¼	20⅛	11	3	18 5/16	4	400	44½	31¾	41	3¾	7¼	36	55¾	42	48
2.50	15	20¼	20¼	11	3	18 5/16	6	400	52	39¾	42	4¼	10⅛	42	59¾	42	60
3.25	20	20¾	24¾	11	4	19⅝	6	400	52	39¾	42	4¼	10⅛	42	59¾	42	60

GASOLINE ENGINES

General Description

GASOLINE engines, used in the charging of moderate sized storage batteries, are generally of the single cylinder four cycle type, water cooled and equipped with the "Make and Break" electric ignition. The vertical type engine is lubricated by the crank dipping into an oil bath in the base of the crank case; oil and grease cups are further provided for lubricating parts not so cared for.

The operation of the engine is maintained at a constant speed by either regulating the mixture of gasoline vapor or by varying the number of power impulses as soon as a certain

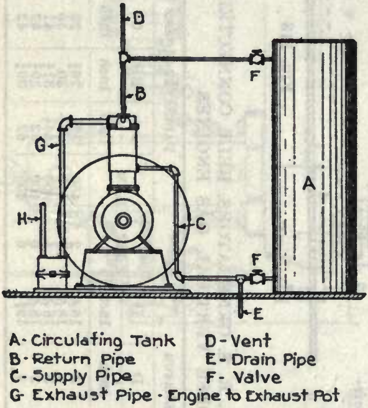


Fig. 114. Water Connections for Gasoline Engine Using Cooling Tank

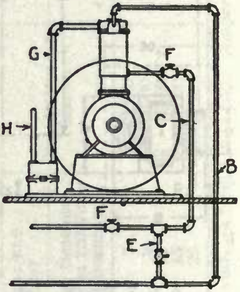


Fig. 115. Water Connections for Gasoline Engine Cooled by Running Water

speed is exceeded; the engines so controlled are known as the "Throttling Governor" or the "Hit and Miss" types, respectively.

In a common type of engine used for this work, a pump supplies gasoline to a reservoir, an overflow pipe being connected with the reservoir to maintain the gasoline at a uniform height. At the proper time in the cycle of operation, the engine piston sucks air through the air inlet passage and at such a velocity that gasoline is picked up from the reservoir and drawn through an adjustable nozzle into the cylinder head, the gasoline mixing with the air to form the required explosive vapor.

Location of Engine

In locating the engine, at least two feet should be left on all sides of engine for convenience in starting and for having sufficient room to make necessary adjustments and repairs.

The gravity system of circulation is generally used for the cooling water. With this system, the tank for the cooling water is generally placed on the floor, as shown in Fig. 114; best results are secured, however, by having the tank elevated enough to bring the bottom above the lower water opening on the engine cylinder. Connections should be as shown, large enough piping being used to permit free circulation of the water. Valves F-F must be inserted in the pipe line to permit drawing off the water from engine in freezing weather without emptying the tank.

The gasoline tank should be located outside of the building,

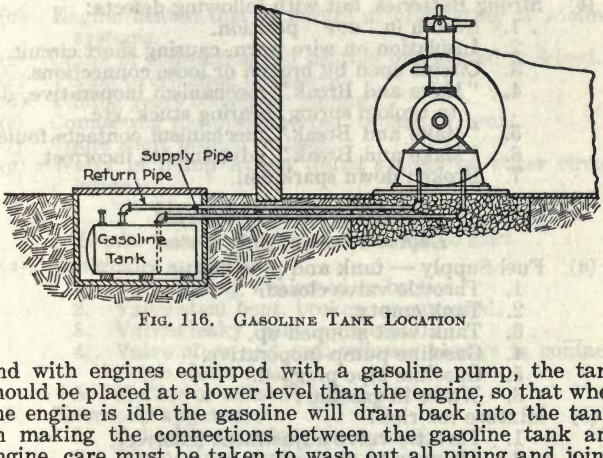


Fig. 116. Gasoline Tank Location

and with engines equipped with a gasoline pump, the tank should be placed at a lower level than the engine, so that when the engine is idle the gasoline will drain back into the tank. In making the connections between the gasoline tank and engine, care must be taken to wash out all piping and joints with gasoline to remove any loose matter or scale from the interior of such connections.

To Start Engine

See that engine is properly oiled and that water and gasoline valves are turned on. Pump gasoline into reservoir. Fill priming cock on head of cylinder; this may not be necessary in warm weather. Make sure that spark lever is in "retard" or "late" position, then close switch to ignition circuit.

Turn engine fly-wheel in normal direction of rotation.

After ignition occurs, remove starting crank, advance spark lever to "early" position and regulate the throttle valve. It will be found that this last adjustment varies with the temperature, requiring much coarser adjustment with cold weather than with warm.

Load should not be thrown on the engine until after it is in operation.

To Stop Engine

Close throttle valve and open switch on battery. If it is freezing weather, water should be drawn off from engine.

GASOLINE ENGINE TROUBLES

Ignition Troubles

Engine misses or fails to start

(*a*) Weakened Batteries.
(*b*) Strong Batteries, but with following defects:
1. Switch in "OFF" position.
2. Insulation on wire worn, causing short circuit.
3. Circuit open by broken or loose connections.
4. "Make and Break" mechanism inoperative, due to broken spring, bearing stuck, etc.
5. "Make and Break" mechanism contacts fouled.
6. "Make and Break" adjustments incorrect.
7. Broken down spark coil.

Carburetion Difficulties

Engine misses or fails to start

(*a*) Fuel Supply — tank and pipe line:
1. Throttle valve closed.
2. Tank empty.
3. Tank vent stopped up.
4. Gasoline pump inoperative.
5. Gasoline pipe plugged.
6. Water in gasoline.

(*b*) Mixture too rich:
1. Throttle valve adjustment incorrect.
2. Air passage clogged.

(*c*) Mixture too weak:
1. Throttle valve adjustment incorrect.
2. Spray valve partially stopped up.
3. Intake pipe leaky.

Loss of Compression

Engine misses, looses power, or fails to start

(*a*) Improper valve operation:
1. Valves do not lift at proper time; due to loosening or stripping of gearing on cam or crank shafts.
2. Valves fail to seat properly or too slow; due to weak spring.

3. Worn cam followers, cams, push rods, etc.
(*b*) Leaky piston rings.
(*c*) Priming valve open or leaky.
(*d*) Leak in cylinder head packing.
(*e*) Failure of lubricating system (engine hot):
1. Oil valve shut off.
2. No oil in oil cups.
3. Oil drained out of crank case (vertical engine).
(*f*) Failure of cooling system (engine hot):
1. Valve in water piping closed.
2. No water in cooling tank.
3. Water below normal level (gravity system of circulation).
4. Water piping plugged.
5. Pump out of order (forced circulation).

Cannot Crank Engine

(*a*) Engine heated due to failure of lubricating or cooling systems.
(*b*) Crank or connecting rod bearing overheated or seized.
(*c*) Piston overheated or seized.
(*d*) Timing gears broken or jammed.
(*e*) Connecting rod disconnected, broken or bent.
(*f*) Crank shaft broken or bent.
(*g*) Water in pump frozen (force system of water circulation).

Mechanical Difficulties

Engine misses, looses power, or fails to start

(*a*) Externally apparent:
1. Valve spring weakened or broken.
2. Valve stem bent, broken, or gummed.
3. Valves leaky (carbon on seats).
4. Valve stem and cam-follower always in contact (no clearance).
5. Muffler or exhaust pipe obstructed.
(*b*) Internally apparent:
1. Cylinders or valves carbonized.
2. Piston rings gummed or broken.
3. Leaky piston rings, slots in line.
4. Cam head worn, shifted or broken.
5. Piston head or cylinder wall cracked.
6. Piston rings and cylinder wall scored.

Loss of Power Without Missing

(*a*) Ignition system adjustments wrongly set.
(*b*) Carbureter adjustments wrongly set.
(*c*) Lubricating system operating imperfectly.
(*d*) Cooling system operating imperfectly.
(*e*) Poor valve operation.
(*f*) Batteries weakened, giving poor spark.

(*g*) Mechanical difficulties, such as worn valve connections, etc.
(*h*) Intake pipe leaky.
(*i*) Muffler or exhaust obstructed.
(*j*) Engine bearings overheated.

EDITOR'S NOTE

Above articles based on data furnished by Fairbanks-Morse & Company.

R. S. A. SPECIFICATIONS FOR GASOLINE ENGINE WITH FUEL AND WATER TANKS (1910)

1. ENGINE

(*a*) The recommended brake horse power of the gasoline engine shall be not less than one and three-fourths (1¾) times the kilowatt capacity of the generator at the maximum voltage and the eight (8) hour charging rate.

(*b*) The engine shall run without injurious vibration and shall operate continuously at Manufacturer's specified capacity for a period of sixteen (16) hours without injurious heating in any part.

(*c*) Regulation in speed shall be within three (3) per cent. from no load to full load and the regulation as recorded on the voltmeter for a given current shall not vary more than two (2) per cent. between impulses.

(*d*) Electrodes on the engine for electric ignition shall be tipped with platinum or an equally serviceable material.

(*e*) Manufacturer's standard exhaust muffler shall be provided.

(*f*) Engine and accessories shall be acceptable by and installed under the rules of the National Board of Fire Underwriters and the attached requirements of local authorities.

(*g*) Engines of twenty-five (25) horse power or less shall not exceed a speed of four hundred (400) r. p. m.

2. TANKS

(*a*) Gasoline tank of............gallons capacity shall be furnished. Fuel and cooling tanks shall be made of iron or steel with brazed or riveted seams.

(*b*) Tanks shall be galvanized after they are put together.

(*c*) For tanks either for fuel or water, selection shall be made, when practicable, from the following table:

Gallons capacity	Inches in diameter	Inches in length	Gauge metal Head	Gauge metal Body
66	18	68	14	16
120	24	66	12	14
500	36	120	10	12

As a guide in ordering tanks, it is good practice to consider that it will require one-tenth (1/10) of a gallon of gasoline per horse power hour for gasoline engines.

(*d*) For cooling, the minimum of free running water should be not less than ten (10) gallons per horse power hour, and for the circulation tank system not less than fifty (50) gallons per horse power.

(*e*) Sufficient piping shall be furnished to locate the gasoline tank .... feet from the engine.

(*f*) Unions in all piping shall be equipped with ground brass seats.

(*g*) Unless otherwise specified, an iron or a steel cooling tank of sufficient capacity for a continuous run of ten (10) hours on one (1) filling, with connections and removable cover, shall be furnished. Connections between engine and tank shall be arranged for convenient and complete drainage of the cooling system, for independent drainage of the engine and tank, and to conduct all waste water and steam to the outside of the building.

(*h*) When engine is installed in same building with storage batteries outside air intake shall be provided.

SWITCHBOARDS

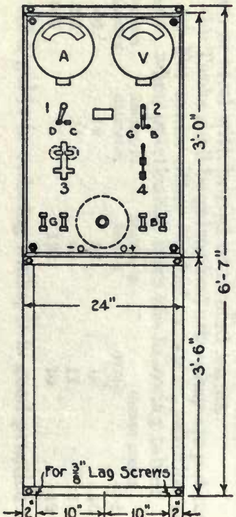


Fig. 117

MANIPULATION CHART

To charge battery and serve
operating board, ... 3 up–4 up
To serve operating board direct
from generator, ... 3 up–4 open
To measure battery voltage, . . 2 B
To measure generator voltage, . 2 G
To measure charging current, . 1 C
To measure discharge current, . 1 D

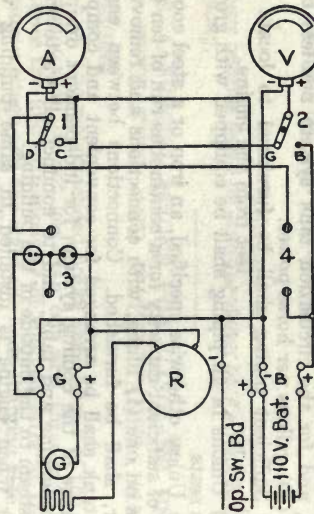


Fig. 118

Standard Power Switchboard for One Generator and One 110 Volt Battery

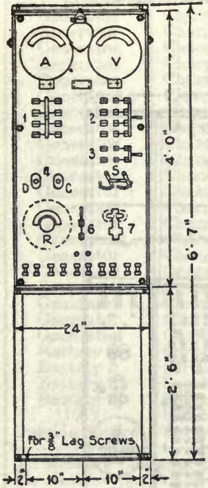


Fig. 119

MANIPULATION CHART

To charge battery 1 from generator,	2 R–3 R–6 up –7 up
To charge batteries 1 and 2 from generator, ...	2 R–3 L–1 L –6 up –7 up
To charge batteries 1 and 3 from generator, ...	2 R–3 L–1 R –6 up –7 up
To charge battery 2 from generator,	2 L–1 L–6 up –7 up
To charge battery 3 from generator,	2 L–1 R–6 up –7 up
To serve interlocker from generator,	2 R–3 R–6 open–7 up
To serve route locking from battery 2, ...	1 R
To serve route locking from battery 3, ...	1 L
To read charging current, ...	4 C
To read battery 1 discharge current,	4 D
To read generator voltage, ...	5 G
To read battery 1 voltage, ...	5 B^1
To read battery 2 voltage, ...	5 B^2
To read battery 3 voltage, ...	5 B^3

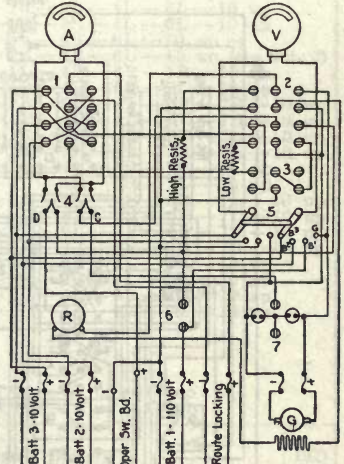


Fig. 120

Power Switchboard for One Generator, One 110 Volt Battery (No. 1) and Two 10 Volt Batteries (Nos. 2 and 3)

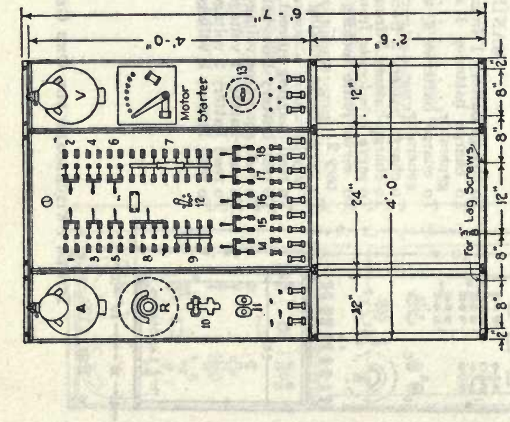


FIG. 121

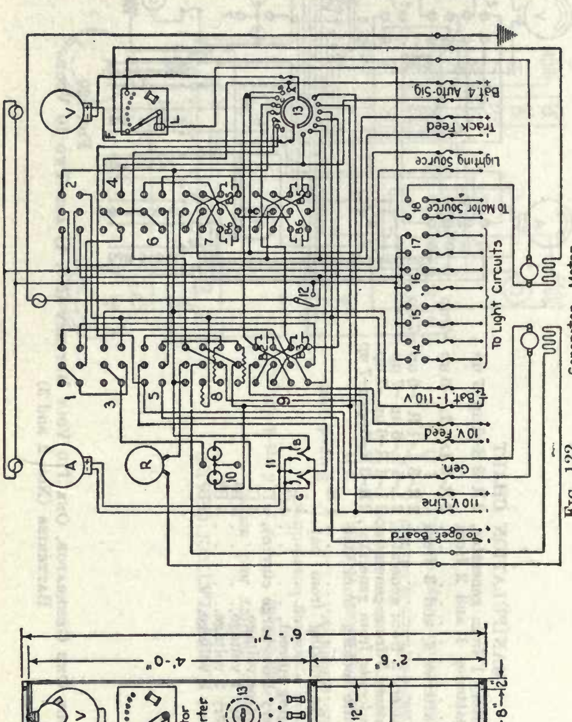


FIG. 122

POWER SWITCHBOARD FOR ONE D.C.-D.C. MOTOR GENERATOR SET, ONE 110 VOLT BATTERY (No. 1), TWO 10 VOLT BATTERIES (Nos. 2 and 3), ONE AUTOMATIC SIGNAL BATTERY (No. 4) AND TWO SETS OF TRACK BATTERIES (Nos. 5 and 6)

MANIPULATION CHART FOR SWITCHBOARD SHOWN ON PRECEDING PAGE

From	Function	Throw Switches (See Note 1)
Generator	Charge Battery 1 and Serve Interlocker, . .	8R — 5R — 3R — 1L — 4L — 6L — 10 up
Generator	Charge Batteries 1-2 and Serve Interlocker, . .	8R — 5R — 3R — 1R — 9L — 4L — 6L — 10 up
Generator	Charge Batteries 1-3 and Serve Interlocker, . .	8R — 5R — 3R — 1R — 9R — 4L — 6L — 10 up
Generator	Charge Battery 4 and Serve Interlocker, . .	8R — 5R — 3L — 1L — 4R — 6L — 10 up or
Generator	Charge Battery 4 and Serve Interlocker, . .	8L — 5R — 3L — 1L — 4R — 6L — 10 up (see Note 2)
Generator	Charge Batteries 1-5 and Serve Interlocker, . .	8R — 5R — 3R — 1L — 4L — 6R — 7R — 10 up
Generator	Charge Batteries 1-6 and Serve Interlocker, . .	8R — 5R — 3R — 1L — 4L — 6R — 7L — 10 up
Generator	Charge Batteries 2-5 and Serve Interlocker, . .	8L — 5R — 3L — 1R — 9L — 4L — 6R — 7R — 10 up
Generator	Charge Batteries 3-5 and Serve Interlocker, . .	8L — 5R — 3L — 1R — 9R — 4L — 6R — 7R — 10 up
Generator	Charge Batteries 2-6 and Serve Interlocker, . .	8L — 5R — 3L — 1R — 9L — 4L — 6R — 7L — 10 up
Generator	Charge Batteries 3-6 and Serve Interlocker, . .	8L — 5R — 3L — 1R — 9R — 4L — 6R — 7L — 10 up
Generator	Charge Batteries 4-5 and Serve Interlocker, . .	8R — 5R — 3L — 1L — 4R — 6R — 7R — 10 up
Generator	Charge Batteries 4-6 and Serve Interlocker, . .	8R — 5R — 3L — 1L — 4R — 6R — 7L — 10 up
Generator	Charge Batteries 2-6-4 and Serve Interlocker, . .	8R — 5R — 3L — 1R — 9L — 4R — 6R — 7L — 10 up
Generator	Charge Batteries 3-6-4 and Serve Interlocker, . .	8R — 5R — 3L — 1R — 9R — 4R — 6R — 7L — 10 up
Generator	Charge Batteries 2-5-4 and Serve Interlocker, . .	8R — 5R — 3L — 1R — 9L — 4R — 6R — 7R — 10 up
Generator	Charge Batteries 3-5-4 and Serve Interlocker, . .	8R — 5R — 3L — 1R — 9R — 4R — 6R — 7R — 10 up
Generator	Charge Battery 2 and Serve Interlocker, . .	8L — 5R — 3L — 1R — 9L — 4L — 6L — 10 up
Generator	Charge Battery 3 and Serve Interlocker, . .	8L — 5R — 3L — 1R — 9R — 4L — 6L — 10 up
Generator	Charge Battery 5 and Serve Interlocker, . .	8L — 5R — 3L — 1L — 4L — 6R — 7R — 10 up
Generator	Charge Battery 6 and Serve Interlocker, . .	8L — 5R — 3L — 1L — 4L — 6R — 7L — 10 up
Battery 2	Serve 10 Volt. Feeders, ...	2R
Battery 3	Serve 10 Volt. Feeders, ...	2L
Battery 5	Serve Track Circuits, ...	7L
Battery 6	Serve Track Circuits, ...	7R
110 V	Serve Light Circuits, ...	2R — 14 up — 15 up — 16 up — 17 up
Outside Source	Serve Light Circuits, ...	2L — 14 up — 15 up — 16 up — 17 up

To Measure Charging Current, ...	11G		
To Measure Current to Interlocker, ...	11B	To Measure Voltage of Battery 3, ...	13D
To Measure Voltage Auto-Signal Battery, ...	13A	To Measure Voltage of Battery 1, ...	13E
To Measure Voltage Track Circuit, ...	13B	To Measure Voltage of Generator, ...	13F
To Measure Voltage of Battery 2, ...	13C	To Measure Voltage of Outside Source, ...	13G

NOTE 1.— When charging batteries from outside source, use same manipulation except switch No. 5 is to be thrown to left.

NOTE 2.— If charging current cannot be reduced low enough with the first manipulation (switch 8 to the right) throw switch 8 to the left; this is necessary on account of the variable number of cells that might be ready for charge.

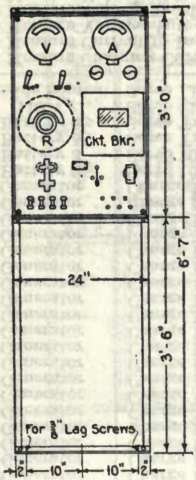


Fig. 123

To test for ground, throw switch 3 to right or left. If lamp lights when pressed to the right it shows that the negative wire is grounded. If lamp lights when pressed to the left it shows that the positive wire is grounded.

Red lamp lighted shows that the circuit breaker is open.

MANIPULATION

To measure generator voltage –1G
To measure battery voltage –1B
To measure charging current–2C
To measure discharge current–2D

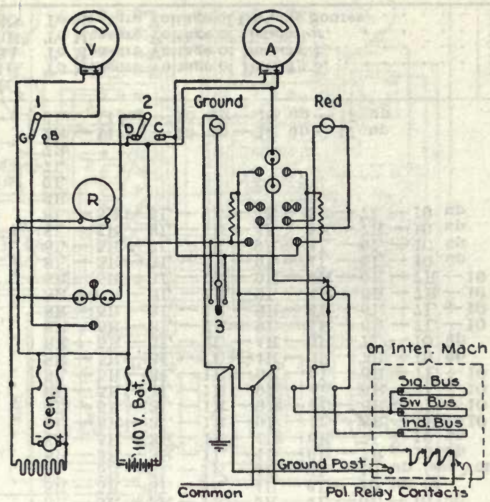


Fig. 124

Power Switchboard for One Generator and One 110 Volt Battery, in Connection with Operating Switchboard

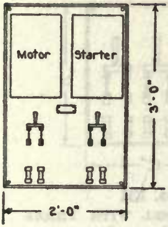


FIG. 125
STARTING PANEL FOR SINGLE PHASE A. C. MOTOR

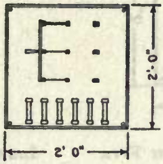


FIG. 126
STARTING PANEL FOR THREE PHASE A. C. MOTOR

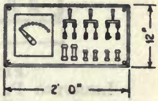


FIG. 127
STARTING PANEL FOR D. C. MOTOR

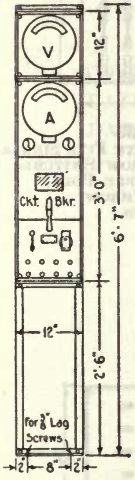


FIG. 128

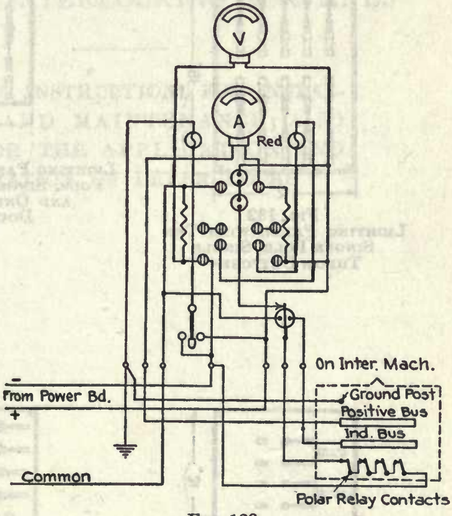


FIG. 129

STANDARD OPERATING SWITCHBOARD

To test for ground, throw switch No. 1 to the right or left. If the lamp lights when pressed to the right it shows that the negative wire is grounded. If lamp lights when pressed to the left it shows that the positive wire is grounded.

Red lamps lighted shows that the circuit breaker is open.

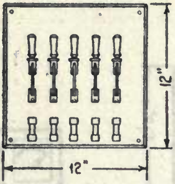


FIG. 130
LIGHTING PANEL WITH FIVE SINGLE POLE, SINGLE THROW SWITCHES

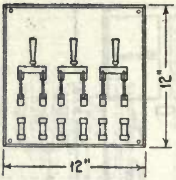


FIG. 131
LIGHTING PANEL WITH THREE DOUBLE POLE, SINGLE THROW SWITCHES

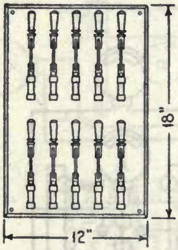


FIG. 132
LIGHTING PANEL WITH TEN SINGLE POLE, SINGLE THROW SWITCHES

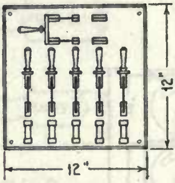


FIG. 133
LIGHTING PANEL WITH FIVE SINGLE POLE, SINGLE THROW SWITCHES AND ONE DOUBLE POLE, DOUBLE THROW SWITCH

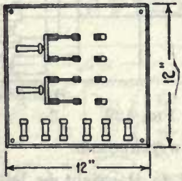


FIG. 134
LIGHTING PANEL WITH TWO DOUBLE POLE, DOUBLE THROW SWITCHES

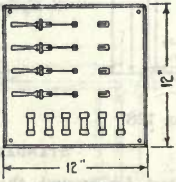


FIG. 135
LIGHTING PANEL WITH FOUR SINGLE POLE, DOUBLE THROW SWITCHES

SECTION VII

INSTALLATION AND OPERATING DATA FOR ELECTRIC INTERLOCKING MACHINES

COVERING INSTRUCTIONS FOR INSTALLATION AND MAINTENANCE; ALSO DATA FOR THE APPLICATION AND OPERATION OF LEVER LOCKS

INSTRUCTIONS COVERING THE INSTALLATION AND MAINTENANCE OF THE MODEL 2 ELECTRIC INTERLOCKING MACHINE

Shipment

BEFORE shipment the interlocking machine is assembled complete in every detail and subjected to a rigid electric and mechanical test. It is then partly disassembled, the levers, lever tappets and locking, the legs and lower tiers of locking plates (if furnished) being boxed separately from the body of the machine. This latter is then divided into sections of approximately forty lever spaces and boxed on skids for shipment. Before boxing, all machined parts are wiped dry and coated with vaseline to guard against the effects of rust during transit.

Storing

Upon the receipt of the machine it should be stored in a dry place. If some time passes before the machine is set up and there is any chance of its different parts rusting, these parts should be wiped dry and recoated with vaseline.

Installation

The first step in the assembly of the machine is to bolt the sections to their supporting legs and the various sections to each other. The legs are numbered and the machine beds marked to correspond. Extreme care should be taken in shimming up under the legs to insure accurate alignment of the bed and an even distribution of the weight on the supporting legs. Failure to do this, especially in a large machine, is very likely to result in binding between the various parts of the mechanical locking.

The second and third tiers of locking plates, if used, should be assembled on the machine, care being taken to place the templet furnished for the purpose in the horizontal and vertical locking slots before doweling the locking plates to their support. Never file the screw holes when mounting these plates since this is not necessary if the bed has its correct alignment. To permit of the plates being placed in the same location as when the machine was assembled in the factory, the second tier of plates are numbered 1, 2, 3, etc., from left to right, and the third tier 1A, 2A, 3A, etc., also from left to right.

The locking should then be assembled in the locking plates and the lever tappets placed in their proper positions. Each locking dog is stamped with the number of the tappet with which the dog is to engage and the locking bars with numbers to correspond with the slot in which they are to be placed, these slots being numbered in sequence from the top of the

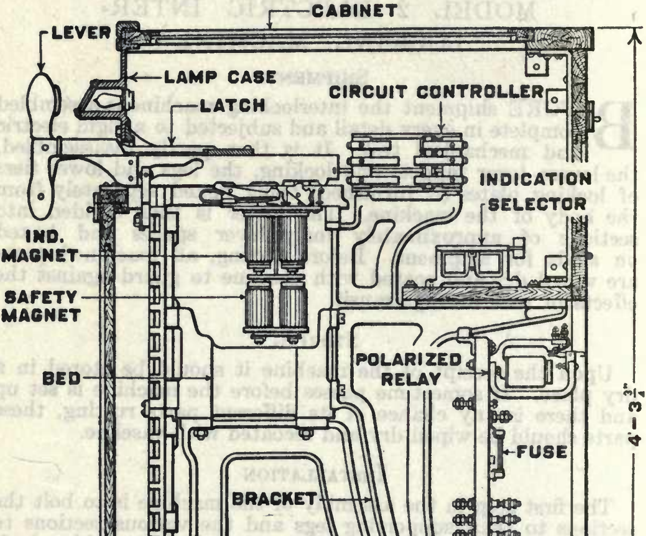


FIG. 136. MODEL 2 UNIT LEVER TYPE INTERLOCKING MACHINE

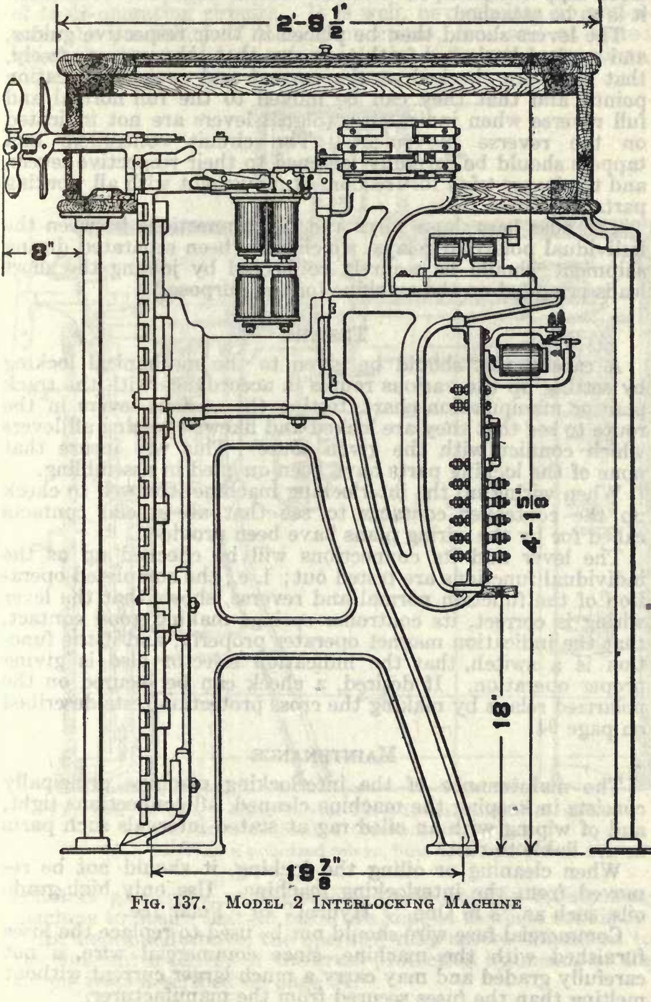


FIG. 137. MODEL 2 INTERLOCKING MACHINE

locking bed to the bottom (thirty-two slots per tier of locking). Each tappet is stamped with the number of the lever to which it is to be attached.

The levers should then be placed in their respective guides, and worked back and forth to insure that they operate freely, that they are checked at the normal and reverse indication points, and that they can be moved to the full normal and full reverse when indicated. (Signal levers are not indicated on the reverse movement.) The circuit controllers and tappets should be carefully fastened to their respective levers, and the levers tried for freedom of movement with all working parts connected.

The buss bars, buss wires and the connections between the individual polarized relays, which have been separated during shipment, should be securely connected by joining the short leads provided on the machine for the purpose.

Testing

A careful test should be given to the mechanical locking by setting up the various routes in accordance with the track plan or manipulation chart, testing the various levers in the route to see that they are locked and likewise testing all levers which conflict with the given route. This will insure that none of the locking parts have been omitted in assembling.

When wiring up the interlocking machine it is well to check up the controller contacts to see that all special contacts called for by the wiring plans have been provided.

The lever and its connections will be checked up as the individual functions are tested out; i. e., the completed operation of the function normal and reverse, shows that the lever wiring is correct, its controller springs making good contact, that the indication magnet operates properly, and if the function is a switch, that the indication selector also is giving proper operation. If desired, a check can be secured on the polarized relays by making the cross protection tests described on page 94.

Maintenance

The maintenance of the interlocking machine principally consists in keeping the machine cleaned, all connections tight, and of wiping with an oiled rag at stated intervals such parts as are liable to rust.

When cleaning or oiling the locking, it should not be removed from the interlocking machine. Use only high-grade oils, such as "3 in One," "Hydrol" or "Polar Ice."

Commercial fuse wire should not be used to replace the fuses furnished with the machine, since commercial wire is not carefully graded and may carry a much larger current without melting than the fuses secured from the manufacturer.

As a general statement, it may be said that the operation of the various functions is a good check on the condition of the interlocking machine, since the completed operation of the various functions gives assurance as to the integrity of all parts of their operating circuits. It is well, nevertheless, to anticipate the possibility of loose connections, etc., and at stated intervals to make inspections of the different connections,

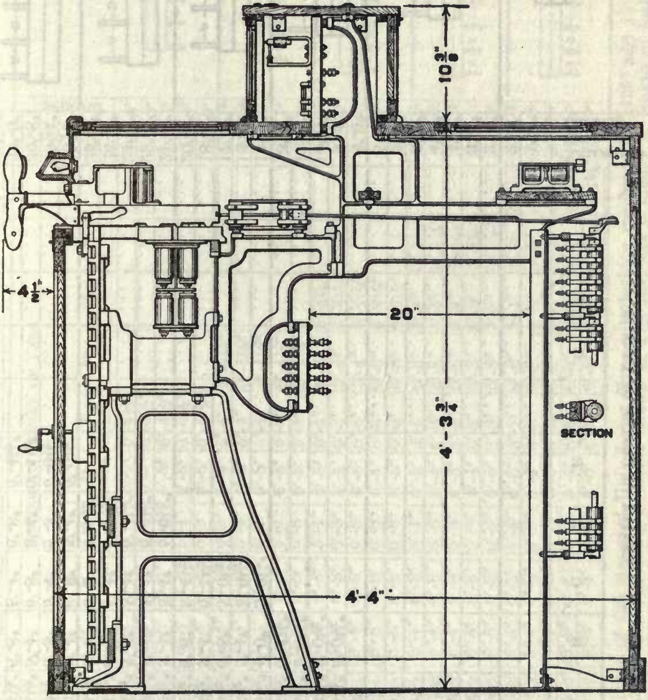


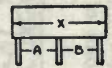
FIG. 138. MODEL 2 UNIT LEVER TYPE INTERLOCKING MACHINE. EQUIPPED WITH SPRING COMBINATION BOARD
Note location of polarized relays, buss bars and fuses.

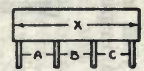
contacts and various mechanical parts on the interlocking machine to insure that all parts are kept in the best condition.

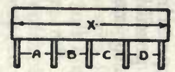
As mentioned above, the operator may assure himself as to the constant integrity of the cross protection by means of the simple tests described on page 94.

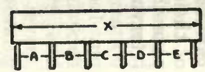
SPACING OF LEGS FOR MODEL 2 INTERLOCKING MACHINES

No. of Levers	Combination of Beds	No. of Legs	No. of Bkts.	Center to Center of Legs: A	B	C	D	E	F	G	H	J	K	X=Length Over Locking
8	1-8	1	2	...	...	...	...	...	...	...	...	...	...	1′-4″
12	1-12	1	3	...	...	...	...	...	...	...	...	...	...	2′-0″
16	1-16	2	3	2′-1″	...	...	...	...	...	...	...	...	...	2′-8″
20	1-20	2	4	2′-9″	...	...	...	...	...	...	...	...	...	3′-4″
24	1-24	2	4	3′-5″	...	...	...	...	...	...	...	...	...	4′-0″
28	1-28	2	5	4′-1″	...	...	...	...	...	...	...	...	...	4′-8″
32	1-32	2	5	4′-9″	...	...	...	...	...	...	...	...	...	5′-4″
36	1-36	2	6	5′-5″	...	...	...	...	...	...	...	...	...	6′-0″
40	1-40	2	6	6′-1″	...	...	...	...	...	...	...	...	...	6′-8″
48	1-48	3	7	7′-5″	...	...	...	...	...	...	...	...	...	8′-0″
56	1-24+1-32	3	9	3′-8½″	5′-0½″	...	...	...	...	...	...	...	...	9′-4″
64	2-32	3	10	5′-0½″	5′-0½″	...	...	...	...	...	...	...	...	10′-8″
72	1-40+1-32	3	11	6′-4½″	5′-0½″	...	...	...	...	...	...	...	...	12′-0″
80	2-40	3	12	6′-4½″	6′-4½″	...	...	...	...	...	...	...	...	13′-4″
88	2-32+1-24	4	14	5′-0½″	4′-0″	5′-0½″	...	...	...	...	...	...	...	14′-8″
96	3-32	4	15	5′-0½″	5′-4″	5′-0½″	...	...	...	...	...	...	...	16′-0″
104	2-32+1-40	4	16	5′-0½″	6′-8″	5′-0½″	...	...	...	...	...	...	...	17′-4″
112	2-40+1-32	4	17	6′-4½″	5′-4″	6′-4½″	...	...	...	...	...	...	...	18′-8″
120	3-40	4	18	6′-4½″	6′-8″	6′-4½″	...	...	...	...	...	...	...	20′-0″
128	4-32	5	20	5′-0½″	5′-4″	5′-4″	5′-0½″	...	...	...	...	...	...	21′-4″
136	3-32+1-40	5	21	5′-0½″	5′-4″	5′-4″	6′-4½″	...	...	...	...	...	...	22′-8″
144	2-40+2-32	5	22	6′-4½″	5′-4″	5′-4″	6′-4½″	...	...	...	...	...	...	24′-0″
152	3-40+1-32	5	23	6′-4½″	6′-8″	5′-4″	6′-4½″	...	...	...	...	...	...	25′-4″
160	4-40	5	24	6′-4½″	6′-8″	6′-8″	6′-4½″	...	...	...	...	...	...	26′-8″
168	4-32+1-40	6	26	5′-0½″	5′-4″	6′-8″	5′-4″	5′-0½″	...	...	...	...	...	28′-0″
176	3-32+2-40	6	27	5′-0½″	6′-8″	5′-4″	6′-8″	5′-0½″	...	...	...	...	...	29′-4″
184	3-40+2-32	6	28	6′-4½″	5′-4″	6′-8″	5′-4″	6′-4½″	...	...	...	...	...	30′-8″
192	4-40+1-32	6	29	6′-4½″	6′-8″	5′-4″	6′-8″	6′-4½″	...	...	...	...	...	32′-0″
200	5-40	6	30	6′-4½″	6′-8″	6′-8″	6′-8″	6′-4½″	...	...	...	...	...	33′-4″



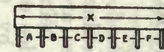
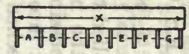
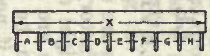
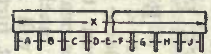
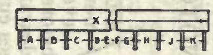






SPACING OF LEGS FOR MODEL 2 INTERLOCKING MACHINES

No. of Levers	Combination of Beds	No. of Legs	No. of Bkts.	Center to Center of Legs A	B	C	D	E	F	G	H	J	K	X=Length Over Locking
208	4-32+2-40	7	32	6′-4½″	5′-4″	5′-4″	5′-4″	5′-4″	6′-4½″	...	...	...	...	34′-8″
216	3-40+3-32	7	33	6′-4½″	5′-4″	5′-4″	6′-8″	5′-4″	6′-4½″	...	...	...	...	36′-0″
224	4-40+2-32	7	34	6′-4½″	6′-8″	5′-4″	5′-4″	6′-8″	6′-4½″	...	...	...	...	37′-4″
232	5-40+1-32	7	35	6′-4½″	6′-8″	6′-8″	5′-4″	6′-8″	6′-4½″	...	...	...	...	38′-8″
240	6-40	7	36	6′-4½″	6′-8″	6′-8″	6′-8″	6′-8″	6′-4½″	...	...	...	...	40′-0″
248	3-40+4-32	8	38	6′-4½″	5′-4″	5′-4″	6′-8″	5′-4″	5′-4″	6′-4½″	...	...	...	41′-4″
256	4-40+3-32	8	39	6′-4½″	5′-4″	6′-8″	5′-4″	6′-8″	5′-4″	6′-4½″	...	...	...	42′-8″
264	5-40+2-32	8	40	6′-4½″	5′-4″	6′-8″	6′-8″	6′-8″	5′-4″	6′-4½″	...	...	...	44′-0″
272	6-40+1-32	8	41	6′-4½″	6′-8″	6′-8″	5′-4″	6′-8″	6′-8″	6′-4½″	...	...	...	45′-4″
280	7-40	8	42	6′-4½″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-4½″	...	...	...	46′-8″
288	4-40+4-32	9	44	6′-4½″	5′-4″	6′-8″	5′-4″	6′-8″	5′-4″	5′-4″	6′-4½″	...	...	48′-0″
296	5-40+3-32	9	45	6′-4½″	5′-4″	6′-8″	6′-8″	5′-4″	6′-8″	5′-4″	6′-4½″	...	...	49′-4″
304	6-40+2-32	9	46	6′-4½″	5′-4″	6′-8″	6′-8″	6′-8″	6′-8″	5′-4″	6′-4½″	...	...	50′-8″
312	7-40+1-32	9	47	6′-4½″	6′-8″	6′-8″	6′-8″	5′-4″	6′-8″	6′-8″	6′-4½″	...	...	52′-0″
320	8-40	9	48	6′-4½″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-4½″	...	...	53′-4″
328	5-40+4-32	10	50	6′-4½″	5′-4″	6′-8″	5′-4″	6′-8″	5′-4″	6′-8″	5′-4″	6′-4½″	...	54′-8″
336	6-40+3-32	10	51	6′-4½″	5′-4″	6′-8″	6′-8″	5′-4″	6′-8″	6′-8″	5′-4″	6′-4½″	...	56′-0″
344	7-40+2-32	10	52	6′-4½″	5′-4″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	5′-4″	6′-4½″	...	57′-4″
352	8-40+1-32	10	53	6′-4½″	6′-8″	6′-8″	6′-8″	5′-4″	6′-8″	6′-8″	6′-8″	6′-4½″	...	58′-8″
360	9-40	10	54	6′-4½″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-4½″	...	60′-0″
368	6-40+4-32	11	56	6′-4½″	5′-4″	6′-8″	5′-4″	6′-8″	5′-4″	6′-8″	5′-4″	6′-8″	6′-4½″	61′-4″
376	7-40+3-32	11	57	6′-4½″	5′-4″	6′-8″	6′-8″	5′-4″	6′-8″	6′-8″	6′-8″	5′-4″	6′-4½″	62′-8″
384	8-40+2-32	11	58	6′-4½″	5′-4″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	5′-4″	6′-4½″	64′-0″
392	9-40+1-32	11	59	6′-4½″	6′-8″	6′-8″	6′-8″	5′-4″	6′-8″	6′-8″	6′-8″	6′-8″	6′-4½″	65′-4″
400	10-40	11	60	6′-4½″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-8″	6′-4½″	66′-8″

NOTE.— For length of cabinet of the standard Unit Lever Type interlocking machine (Fig. 136) add 11 inches to length of locking. For length of cabinet of interlocking machine shown in Fig. 137, add 8 inches to length of locking.

INSTRUCTIONS FOR CUTTING AND TESTING NOTCHES FOR LEVERS CONTROLLED BY LEVER LOCKS

WHERE lever locks are applied to machines before shipment from the factory, the notches are cut in the levers as nearly right as possible, it being understood that before the machines are put into service on the ground the clearance will again be checked up by test and the notches cut out further, if necessary, to give the proper clearance. This clearance should be at least equal to that indicated below when the lever in question is locked by other levers through the medium of the tappet locking, and also when said lever is pulled or pushed hard in either direction to take up all lost motion, the lever latch being lifted at the time.

The lever should be tested as above for clearance for every combination that locks it.

In making the test for clearance, proceed as follows:

With the lever full normal (Fig. 139), set up some one combination that locks it; lift lever lock (A) by applying current, also the lever latch (B), and pull the lever strongly toward the reverse position, as indicated by the arrow, thus taking up all lost motion, and then with a scriber mark this position of the lever. Then drop the lever lock by cutting off the current, release mechanical locking that is holding the lever, and again pull the lever toward the reverse position until it takes up against the lever lock, and again mark the position of the lever with a scriber. The distance between these scriber marks will then tell the clearance "D" existing. Repeat this process for every combination that locks the lever in its normal position, and if the clearance "D" thus found is less than one-eighth inch, the notch in the lever is to be cut out further to give the proper clearance.

Then with the lever full reverse (Fig. 140), set up some one combination that locks it; lift lever lock (A) by applying current to it, also the lever latch (B), and push the lever strongly toward the normal position as indicated by the arrow, thus taking up all lost motion, and then with a scriber mark this position of the lever. Then drop the lever lock by cutting off the current, release the mechanical locking that is holding the lever, and again push the lever toward the normal position until it takes up against the lever lock, and again mark the position of the lever with a scriber. The distance between the two scriber marks will then tell the clearance "D" existing for the reverse position of the lever. Repeat this process for every combination that locks the lever in its reverse position, and if the minimum clearance "D" thus found is less than three-sixteenths inch, the notch in the lever is to be cut out further to give the proper clearance.

Tests must also be made to determine that the clearance (C) is sufficient to permit the lock to drop into its notch when the lever is pushed as far normal as it is possible to get it, or is pulled as far reverse as it is possible to pull it. This clearance "C" can be checked by causing the lock plunger to be raised

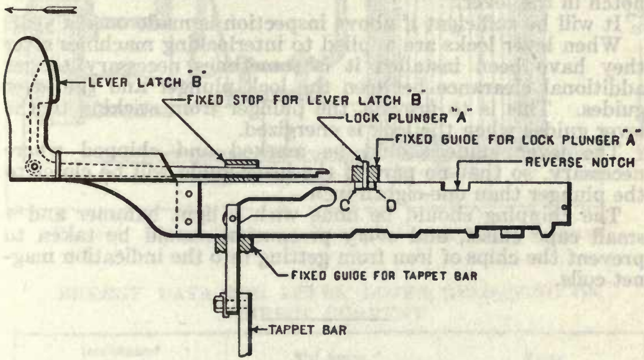


Fig. 139. Notching of Lever for Lever Lock. Normal Position

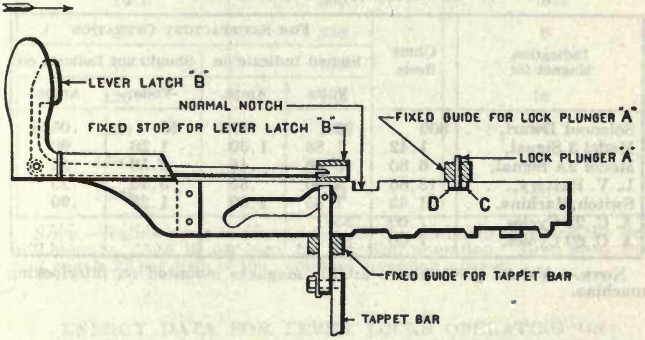


Fig. 140. Notching of Lever for Lever Lock. Reverse Position

and lowered, by making and breaking the circuit thus applying energy to the lock, and if the plunger drops into the notch it is known that the clearance is there.

In cutting the notches see that the corners are left square and the surface that comes against the lock plunger is vertical, so that there may be no tendency to force the lock plunger out by pulling hard on the lever.

Test each lock by putting on and taking off current several times to see that it works properly. If proper, its operation will be quick and sharp.

Interlocking levers should be tested periodically when in service, in accordance with above instructions, to see that sufficient clearance exists between the lock plunger and the notch in the lever.

It will be sufficient if above inspection is made once a year.

When lever locks are applied to interlocking machines after they have been installed it is sometimes necessary to get additional clearance between the lock plunger and the lever guides. This is to prevent the plunger from sticking to the lever guides when the lock is energized.

The lever guide should be marked and chipped where necessary, so that no part of the lever guide will be closer to the plunger than one-eighth inch.

The chipping should be done with a light hammer and a small cape chisel, and every precaution should be taken to prevent the chips of iron from getting into the indication magnet coils.

ENERGY DATA FOR INDICATION MAGNETS FOR MODEL 2 INTERLOCKING MACHINE

Indication Magnet for	Ohms Resis.	For Satisfactory Operation			
		Should Indicate on		Should not Indicate on	
		Volts	Amps.	Volts	Amps.
Solenoid Dwarf, . .	800	90	.112	50	.0625
Model 3 Signal, . .	1.42	1.85	1.30	1.28	.90
Model 2A Signal, .	6.80	3.06	.45	2.58	.38
L. V. Battery,. . .	13.60	4.35	.32	3.40	.25
Switch Machine, . .	1.42	1.85	1.30	1.28	.90
A. C. 25 Cycles, . .	7.00	35	....	....	....
A. C. 60 Cycles, . .	7.00	85	....	....	....

NOTE.—Values given above are for magnets mounted on interlocking machine.

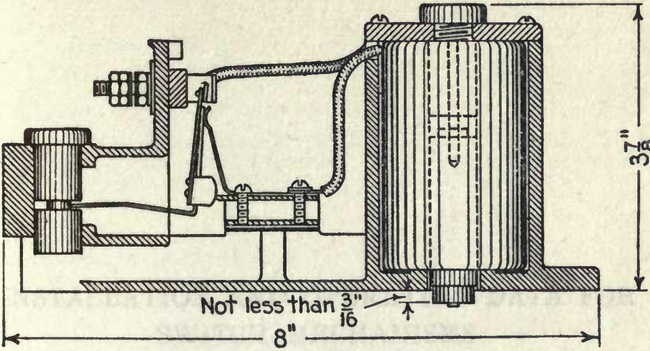


FIG. 141. LEVER LOCK FOR MODEL 2 INTERLOCKING MACHINE

ENERGY DATA FOR LEVER LOCKS OPERATING ON DIRECT CURRENT

Resistance Ohms	Mil Amps.	Volts
14.5	360	5.2
35	238	8
75	173	13
120	133	16
250	120	30
1400	46	64
1500	53	80

NOTE.—Values given in above table are the minimum on which the lock will operate. Add 10 per cent. for practical operation. Drop away current equals 23 per cent. of the minimum operating current.

ENERGY DATA FOR LEVER LOCKS OPERATING ON ALTERNATING CURRENT

Resistance Ohms	Frequency	Volts
35	25 cycles	25
8.6	60 cycles	25

NOTE.—Values given in above table are the minimum on which the lock will operate. Add 10 per cent. for practical operation. Drop away voltage equals 50 per cent. of the minimum operating voltage.

Solenoid Dwarf,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Model 2 Signal,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Model 2A Signal,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L. V. Button,	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Switch Machine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note.— Values [illegible] magnets.

INSTALLATION AND OPERATING DATA FOR SWITCH MECHANISMS

COVERING INSTRUCTIONS FOR INSTALLATION AND MAINTENANCE, ENERGY FIGURES, CLEARANCES REQUIRED, DIMENSIONS, TIE FRAMINGS, STANDARD LAYOUTS, AND TYPICAL CIRCUITS; ALSO DATA ON DETECTOR BAR FITTINGS, SWITCH CIRCUIT CONTROLLERS AND BRIDGE CIRCUIT CLOSERS

INSTRUCTIONS COVERING THE INSTALLATION AND MAINTENANCE OF THE MODEL 2 SWITCH MACHINE

Storing Mechanisms

ALL mechanisms and motors should be placed right side up on timbers to raise them above the ground. The pole changers should be housed in a dry place.

Installation

In making the installation, the first operation is the framing of the ties. This should be in accordance with the plan shown by Fig. 142. All slots cut into the ties should be carefully cleaned of dirt, chips, etc., before the tie plate is put down and the gearing assembled.

Unless special features are required, all holes in the tie plate are drilled before leaving the factory, with the exception of those for the toe and slide plates. These should be so located

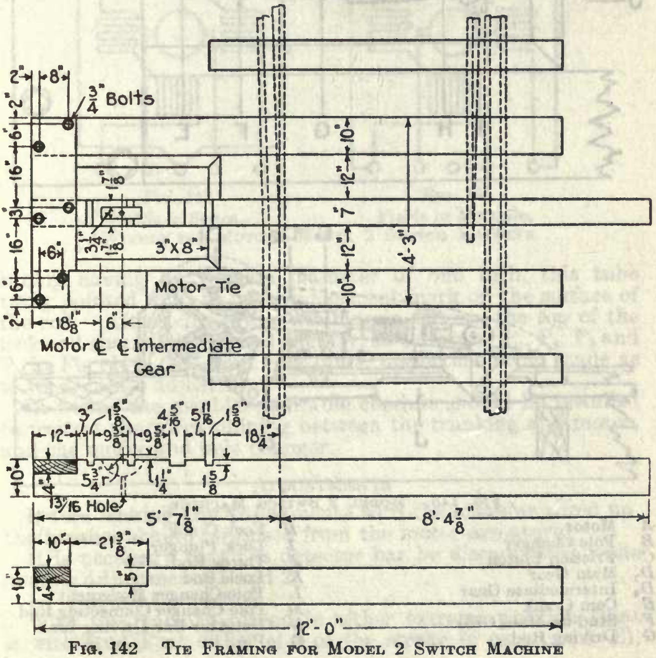


Fig. 142 Tie Framing for Model 2 Switch Machine

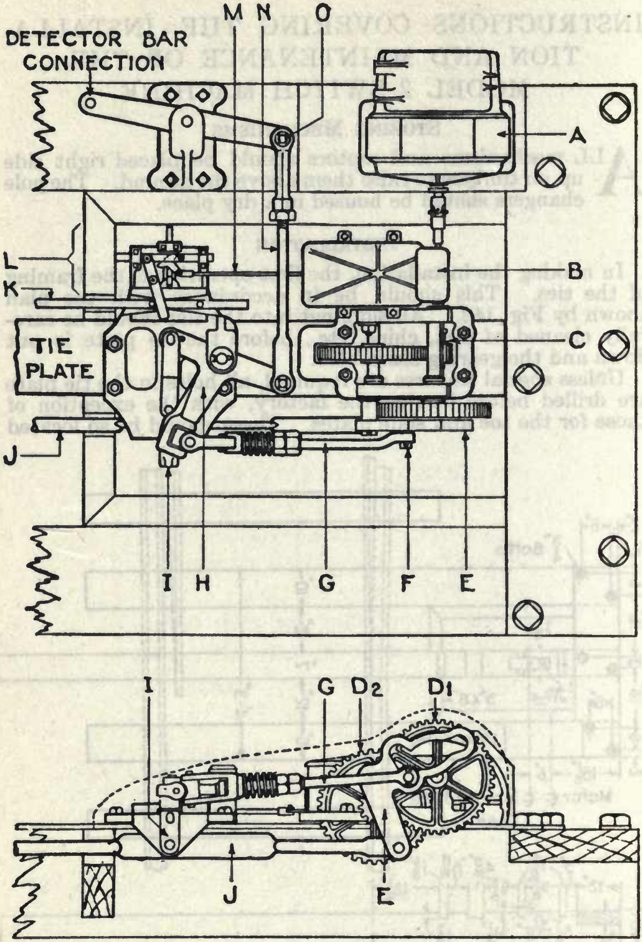


Fig. 143. Model 2 Switch Machine

A	Motor	*H*	Lock Crank
B	Pole Changer	*I*	Lock Plunger
C	Friction Clutch	*J*	Throw Rod
D_1	Main Gear	*K*	Lock Rod
D_2	Intermediate Gear	*L*	Pole Changer Movement
E	Cam Crank	*M*	Pole Changer Connecting Rod
F	Stud on Main Gear	*N*	Detector Bar Driving Link
G	Driving Rod	*O*	Pin

that, when the slide plates, toe plates, and rail braces are in place, the proper track gauge will be rigidly maintained.

The various parts of the switch machine, with the exception of the locking plunger, should then be assembled. In placing the motor, care should be taken to secure proper alignment of the connection between the motor and main gear.

The throw and lock rods may be connected at this time and the lock plunger holes in the throw rod drilled. The lock rod, however, should not be drilled until it is certain that the track has its final alignment and the rail braces have been fitted, thus insuring that there will be no change in the relative position of the switch points and switch mechanism. Special care should be taken when marking the lock rod to see that the switch points are brought tightly up against the stock rail. The most accurate method of marking the rods is to withdraw the lock plunger and to insert in its place a piece of steel

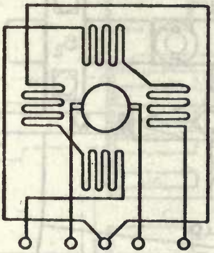


Fig. 144
Fields in Series.

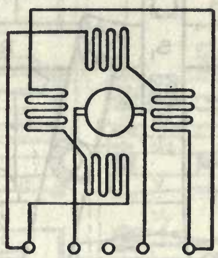


Fig. 145
Fields in Multiple.

Wiring for Motors, Model 2 Switch Machine

tubing having an outside diameter of one inch, this tube being pointed so as to make a clear cut mark on the surface of the rod. After putting the machine in service, the top of the lock rod should be notched slightly, as shown by P_1, P_2, P_3 and P_4 in Fig. 146, to permit of a quick inspection being made as to its accurate adjustment.

In wiring the machine, suitable conduit should be installed to protect the wires running between the trunking and motor, and the motor and pole changer.

Adjustments

Before making any adjustments with the machine wired up, the brushes should be raised from the motor armature.

It is necessary that the detector bar be disconnected while making adjustments 1 and 2.

1. *Plunger Connection.*

With the machine placed in either extreme position (that is with stud F at either end of the stroke in cam crank E), the driving rod G should be adjusted to such a length that the end of lock plunger I will be flush with the outside face of the lock frame (see Fig. 146). This adjustment never varies, and it should not be changed after once being made correctly. If incorrectly made it is liable to cause indication failure.

2. *Pole Changer Movement.*

When locating pins in the lock rod K for the operation of the pole changer movement, move the switch machine to the extreme position as shown in Fig. 143. Locate pin Q_1 so that link R will just clear cap S_1 by five-sixteenth inch (Fig. 146).

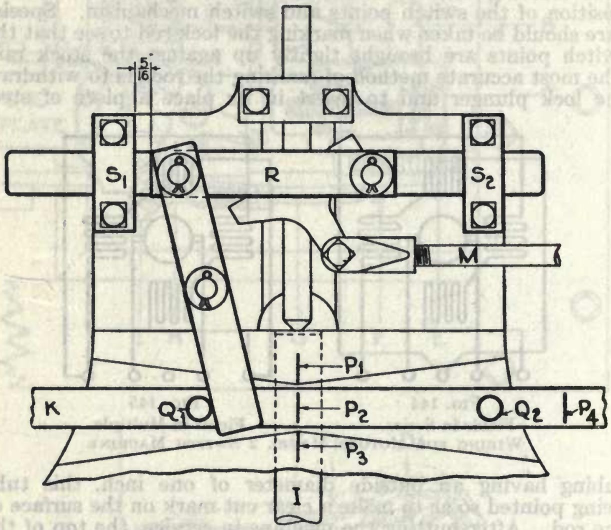


FIG. 146. POLE CHANGER MOVEMENT L FOR MODEL 2 SWITCH MACHINE

Lock plunger I is shown at end of its travel and not in position corresponding with that of link R.

Then throw the switch to the other extreme position and locate pin Q_2 in a similar manner. When assembling the pins on the lock rod, drill, tap, and countersink the lock rod as shown in Fig. 148.

3. *Pole Changer Connection.*

Any lost motion between the pole changer movement L and the pole changer B must be equal at the full normal and full reverse position of the switch machine. To secure this, adjust the connecting rod M with the switch machine in either of its extreme positions. Test with the machine first in the full normal position and then in the full reverse position, pushing and pulling the rod M strongly to determine the total distance it is possible to be moved. Repeat the adjustment until the desired result is obtained. This adjustment never varies in service and it should not be changed after once being made correctly. If it is not made correctly it is very liable to prevent the indication being given on the movement of the switch to the position where the greatest lost motion exists.

4. *Pole Changer Commutator.*

The commutator T (Fig. 147) must revolve freely in its bearings, care being taken that the contact springs U_1, U_2 and U_3 do not have so much tension as to prevent spring V from snapping the commutator over. Adjust so that with machine full normal or reverse, roller W and pin X are in the

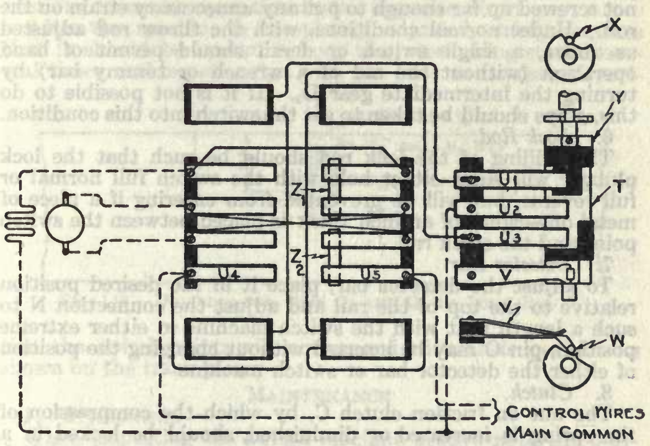


FIG. 147. POLE CHANGER WIRING, MODEL 2 SWITCH MACHINE

relative positions shown. The adjustment of the commutator must be such that the snapping action will take place at such a time that the amount of movement in the contact blocks Z_1 and Z_2, which precedes the snapping action, will be equal for the normal or reverse movement. To be certain that this result is obtained it will be necessary to move the mechanism a number of times by hand very slowiy. Failure to have the adjustment right will be almost certain to result in damage to the insulating cylinder, due to arcing between the contact spring and the contact cylinder, and may prevent indication.

The contact springs U_1 and U_3 are provided with slots which will permit the springs, when resting on the insulated portion of the commutator, to be centrally located.

After the commutator adjustments have been completed and machine worked sufficiently to insure correct action, remove one of the set screws from the collar Y, drill into the shaft and replace the screw, running it down until it locks the commutator to its shaft; repeat this operation with the other screw located in the collar.

In connecting up the operating coils to the contact springs U_1 and U_3, be sure to see that when the commutator is in its full normal or full reverse position, the contact spring which rests on the metal cylinder does not carry current. This can be done by lifting it slightly; if a spark results it shows that the contact springs should be interchanged.

5. *Throw Rod.*

The nuts on the throw rod must be placed so that the switch points will be brought up against the stock rail snugly, but not screwed up far enough to put any unnecessary strain on the rod. Under normal conditions, with the throw rod adjusted as above, a single switch or derail should permit of hand operation (without the aid of a wrench or tommy bar) by turning the intermediate gear D_2. If it is not possible to do this, steps should be taken to get the switch into this condition.

6. *Lock Rod.*

The drilling of the lock rod should be such that the lock plunger will enter either hole with the switch full normal or full reverse, but will be prevented from entering if a piece of metal one-eighth of an inch thick is placed between the switch point and the stock rail.

7. *Detector Bar.*

To adjust the detector bar, place it in the desired position relative to the top of the rail and adjust the connection N to such a length that with the switch machine in either extreme position, pin O may be inserted without changing the position of either the detector bar or switch machine.

8. *Clutch.*

The nut on friction clutch C, by which the compression of the spring is increased or diminished, should be locked in a position which will enable the motor to operate the switch under normal conditions, but will permit the clutch to slip if there is an obstruction in the switch points. This is determined by starting with the nut unscrewed and gradually tightening it up until the motor operates the switch without any slipping of the clutches.

Before any adjustments are made on the friction clutch, separate the cones from the pinion and oil the clutch cones.

Testing

The preferred method of testing the operation of the switch mechanism is to operate it by hand, making sure that the motor brushes are raised before attempting to move the machine. This method should be employed as a regular practice.

If it should become necessary to operate the switch by power, the tests on the switch machine should be carried on under the protection of the operating lever, whenever the conditions are such that the leverman can readily receive and act on signals given him by the man on the ground.

On the rare occasions when it is not practical to conduct the test under the control of its lever, power may be applied locally by taking both control wires off from their respective binding posts (for contact springs U_4 and U_5, Fig. 147) in the pole changer, and having first connected spring U_2 with a short piece of wire to the open control contact spring (spring U_4, Fig. 147), current may be sent through the motor by placing the energized control wire in connection with the other control contact spring (spring U_5, Fig. 147); with these connections the mechanism will be brought to rest upon the completion of its movement without shock. Reverse these connections to secure operation in the opposite direction.

After the machine is completely adjusted, safety requires that it should be operated from the interlocking station several times, making sure that with the lever in its normal posi-

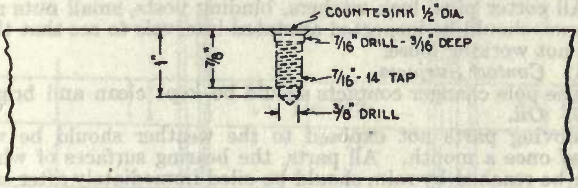


FIG. 148. DRILLING FOR PINS Q_1 AND Q_2 IN LOCK ROD K

tion the switch points will correspond with their position as shown on the track plan.

MAINTENANCE

1. *Mechanism.*

When inspecting the switch machine always note the position of the lock plunger relative to the face of lock frame. If it is not flush with the outside face of the lock frame, make sure that stud F is in the corner of cam crank E. With the switch adjusted correctly and the stud F at the end of its travel, there are two conditions which would be responsible for the plunger not reaching its proper position.

First — The rails may have shifted and altered the throw of the switch points, which will put an unusual strain on the switch machine and prevent the full movement of the lock plunger. This will be determined by operating the switch by hand.

Second — The detector bar may have been thrown out of adjustment by the shifting of the rails, this preventing the generation of the indication current. Necessity for readjustment is determined by disconnecting the bar, placing it in proper position and the switch machine in either extreme position; if it is not possible to replace the pin O without moving either the machine or detector bar, the connections should be readjusted.

On each inspection examine the friction clutch to see that it slips properly on overload.

2. *Motor.*

The motor commutator or brushes should not be disturbed unless found necessary. If the commutator becomes dirty, it should be cleaned with chamois skin moistened with oil, any surplus oil being wiped off the commutator by a dry piece of chamois.

If it becomes necessary to put a new brush into a motor, the brush after being put in position should be seated to the commutator by drawing thin, fine sandpaper under the brush, at the same time pressing the brush against the commutator; the smooth side of the sandpaper should be against the commutator. Use for this purpose "00 Single Finishing Flint Sandpaper."

3. *Small Parts.*

All cotter pins, lock washers, binding posts, small nuts and screws, should be inspected at stated intervals to see that they are not working loose.

4. *Contact Surfaces.*

The pole changer contacts should be kept clean and bright.

5. *Oil.*

Moving parts not exposed to the weather should be well oiled once a month. All parts, the bearing surfaces of which can be reached by rain, should be oiled immediately after each storm. The friction clutches should be oiled on each inspection trip.

INSTRUCTIONS COVERING THE INSTALLATION AND MAINTENANCE OF THE MODEL 4 SWITCH MACHINE

Storing Mechanisms

ALL mechanisms and motors should be placed right side up on timbers to raise them above the ground.

Installation

In making the installation, the first operation is the framing of the ties. This should be in accordance with the plan shown by Fig. 149.

Unless special features are required, all holes in the tie plate

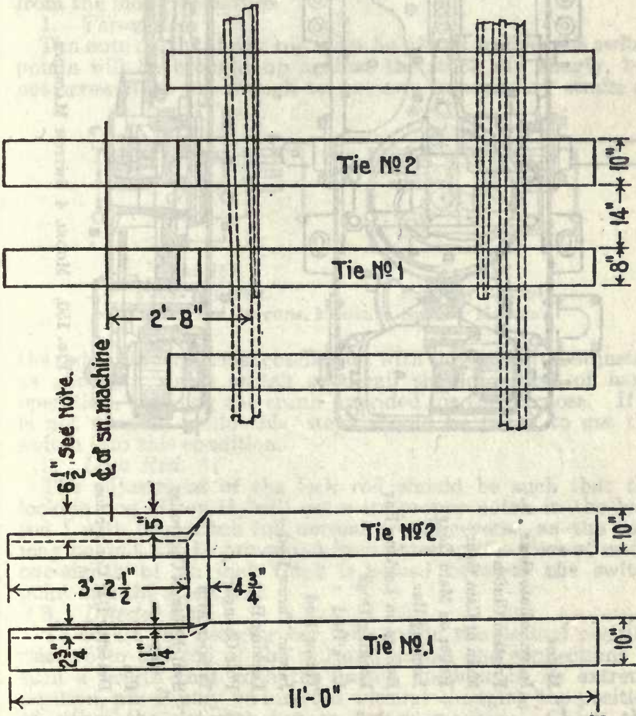


Fig. 149. Tie Framing for Model 4 Switch Machine
Ties to be cut as shown in dotted lines for electrified roads using third rail.

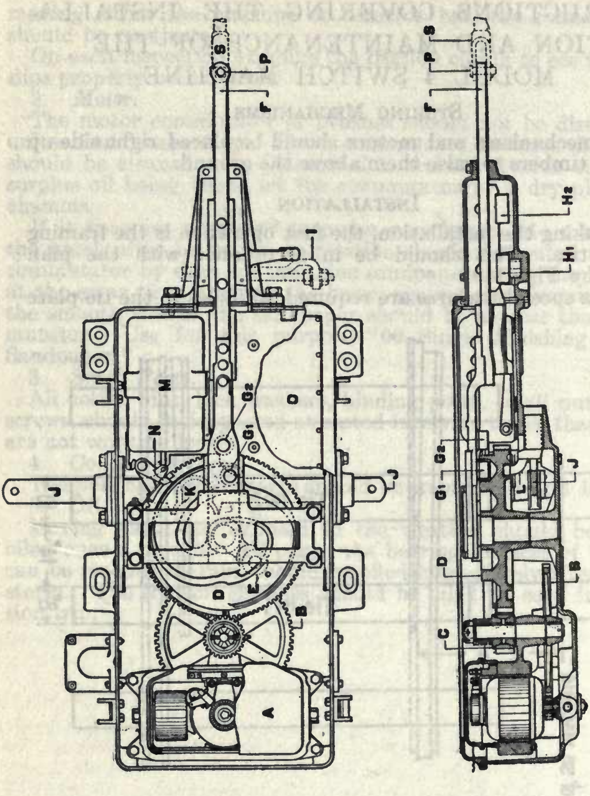


FIG. 150. MODEL 4 SWITCH MACHINE

- *A* Motor
- *B* Intermediate Gear
- *C* Friction Clutch
- *D* Main or Cam Gear
- *E* Roller on Main Gear
- *F* Locking Bar
- G_1–G_2 Rollers on Locking Bar
- H_1–H_2 Locking Dogs
- *I* Lock Rod
- *J* Throw Rod
- *K* Jaw in Throw Rod
- *L* Locking Bolt
- *M* Pole Changer
- *N* Tripper Arm
- *O* Switch Circuit Controller Location
- *P* Pin
- *S* Detector Bar Connection

are drilled before leaving the factory, with the exception of those for the toe and slide plates. These should be so located that when the slide plates, toe plates, and rail braces are in place, the proper track gauge will be rigidly maintained.

The switch machine should then be bolted down to the tie plate and the throw and lock rods connected.

ADJUSTMENTS

As the switch machine is completely assembled in the factory and all parts adjusted to meet the conditions under which the mechanism is to operate, there is very little in the way of adjustments necessary to be made.

After the machine is wired up, before making any adjustments which may be required, the brushes should be raised from the motor armature.

1. *Throw Rod.*

The nuts on the throw rod must be placed so that the switch points will be brought up against the stock rail snugly, but not screwed up far enough to put any unnecessary strain on

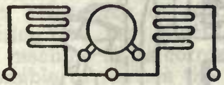


FIG. 151
Fields in Series.

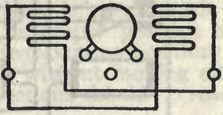


FIG. 152
Fields in Multiple.

WIRING FOR MOTORS, MODEL 4 SWITCH MACHINE

the rod. Under normal conditions, with the throw rod adjusted as above, a single switch or derail should permit of hand operation, by using the crank provided for the purpose. If it is not possible to do this, steps should be taken to get the switch into this condition.

2. *Lock Rod.*

The adjustment of the lock rod should be such that the locking dog H_1 or H_2 will enter its proper notch in the lock rod I with the switch full normal or full reverse, as the case may be, but will be prevented from entering if a piece of metal one-eighth of an inch thick is placed between the switch point and the stock rail.

3. *Detector Bar.*

To adjust the detector bar, place it in the desired position relative to the top of the rail and adjust the connections to such a length that with the switch machine in its extreme position, pin P may be inserted without changing the position of either the detector bar or switch machine. Check this adjustment with the bar and switch machine in the opposite position and readjust if necessary.

4. *Clutch.*

The nut on friction clutch C, by means of which the compression of the spring is increased or diminished should be locked in a position which will enable the motor to operate the switch under normal conditions, but will permit the clutch to slip if there is an obstruction in the switch points. This is determined by starting with the nut unscrewed and gradually tightening it up, until the motor operates the switch without any slipping of the clutches.

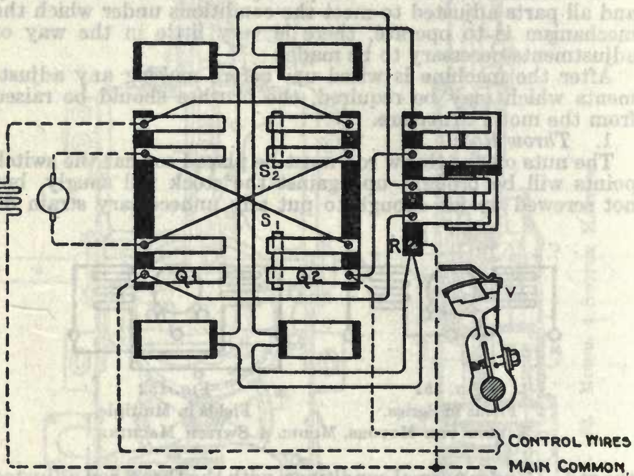


FIG. 153. POLE CHANGER WIRING, MODEL 4 SWITCH MACHINE

TESTING

The preferred method of testing the operation of the switch mechanism is to operate it by hand by means of the crank provided for this purpose, first making sure that the motor brushes are raised before attempting to move the machine. This method should be employed as a regular practice.

If it should become necessary to operate the switch by power, the tests on the switch machine should be carried on under the protection of the operating lever, whenever the conditions are such that the leverman can receive and act on signals given him by the man on the ground.

On the rare occasions when it is not practical to conduct the test under the control of its lever, power may be applied locally by taking both control wires off from their respective binding posts (for contact springs Q_1 and Q_2, Fig. 153) in the pole changer, and having first connected common post R with a short piece of wire to the open control contact spring

(spring Q_1, Fig. 153), current may be sent through the motor by placing the energized control wire in connection with the other control contact spring (spring Q_2, Fig. 153); with these connections the mechanism will be brought to rest without shock upon the completion of its movement. Reverse these connections to secure operation in the opposite direction.

After the machine is completely adjusted, safety requires that it should be operated from the interlocking station several times, making sure that with the lever in its normal position, the switch points will correspond with their position as shown on the track plan.

MAINTENANCE

1. *Mechanism.*

Shifting of the rails may prevent correct operation of the switch machine in the following manner:

First — By altering the throw of the switch points, an unusual strain will be put on the switch machine which will prevent the mechanism from locking up. This will be determined by operating the switch by hand.

Second — The detector bar may have been thrown out of adjustment, this preventing the generation of the indication current. Necessity of readjustment is determined by disconnecting the bar, placing it in proper position and the switch machine in its corresponding extreme position; if it is not possible to replace the pin P without moving either the machine or detector bar, the connections should be readjusted.

2. *Motor.*

The motor commutator or brushes should not be disturbed unless found necessary. If the commutator becomes dirty, it should be cleaned with chamois skin moistened with oil, any surplus oil being wiped off the commutator by a dry piece of chamois.

If it becomes necessary to put a new brush into a motor, the brush after being put in position should be seated to the commutator by drawing thin, fine sandpaper under the brush, at the same time pressing the brush against the commutator; the smooth side of the sandpaper should be against the commutator. Use for this purpose "00 Single Finishing Flint Sandpaper."

3. *Small Parts.*

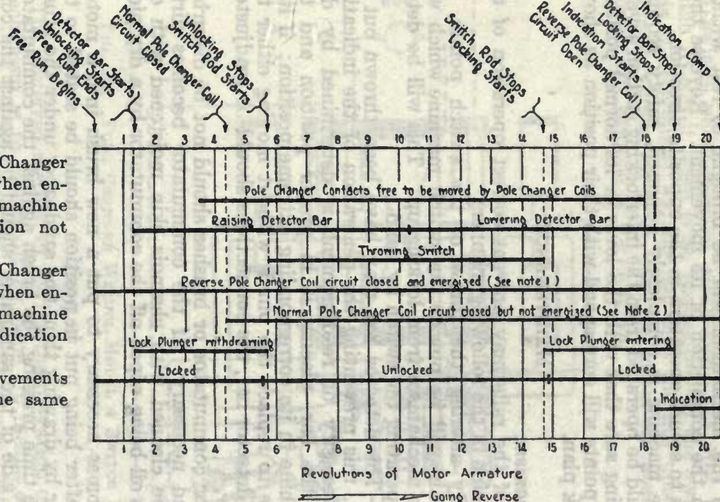
All cotter pins, lock washers, binding posts, small nuts and screws, should be inspected at stated intervals to see that they are not working loose.

4. *Contact Surfaces.*

The switch circuit controller and pole changer contacts should be kept clean and bright.

5. *Oil.*

Moving parts not exposed to the weather should be well oiled once a month. All parts, the bearing surfaces of which can be reached by rain, should be oiled immediately after each storm.



NOTE 1.—"Reverse Pole Changer Coils" are the ones which, when energized, cause the switch machine to reverse, normal indication not having been received.

NOTE 2.—"Normal Pole Changer Coils" are the ones which, when energized, cause the switch machine to go normal, reverse indication not having been received.

NOTE 3.—Cycle of movements "Going Normal" is in the same order as "Going Reverse."

FIG. 154. CYCLE OF MOVEMENTS OF MODEL 2 SWITCH MACHINE

NOTE 1.—"Reverse Pole Changer Coils" are the ones which, when energized, cause the switch machine to reverse, normal indication not having been received.

NOTE 2.—"Normal Pole Changer Coils" are the ones which, when energized, cause the switch machine to go normal, reverse indication not having been received.

NOTE 3.—"Tripper Dog" is the device which is operated by cam on main gear and mechanically operates the pole changer.

NOTE 4.—Cycle of movements "Going Normal" is in the same order as "Going Reverse."

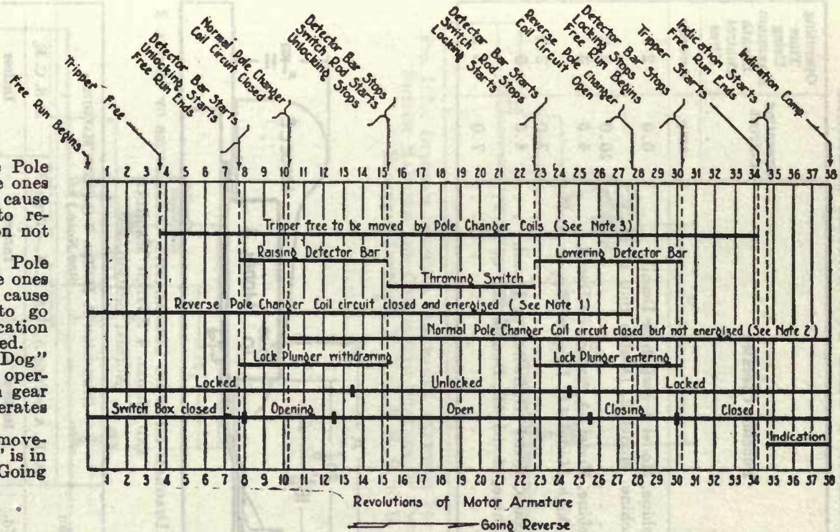


FIG. 155. CYCLE OF MOVEMENTS OF MODEL 4 SWITCH MACHINE

OPERATING DATA FOR SWITCH MACHINES

Function Operated	Operating Current	Operating Time Using Maximum Length Control Wires
	Amp.	Seconds
Switch Machine, Model 2, Switch or Derail, . . .	6.0	2
Switch Machine, Model 2, Double Slip or M. P. Frog, ...	10.0	2.2
Switch Machine, Model 4A, Switch or Derail,. . .	4.5	3
Switch Machine, Model 4A, Double Slip or M. P. Frog, ...	7.0	3.2
Switch Machine, Model 4B, Switch or Derail,. . .	4.5	3
Switch Machine, Model 4B, Double Slip or M. P. Frog, ...	7.0	3.2

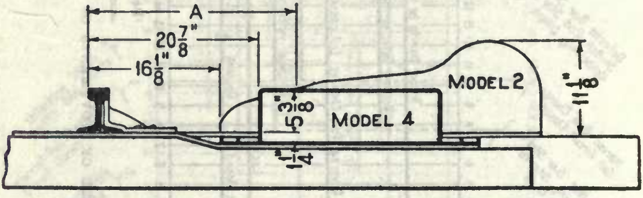


Fig. 156. Diagram Showing Comparative Clearances of Model 2 and Model 4 Switch Machine
Normal location.

Rail Section	Dimension A Model 2 Switch Machine (See Note.)		
	A. R. A.—Type A.	A. R. A.—Type B.	A. S. C. E.
Lbs. per Yd.	Inches	Inches	Inches
60	$22\frac{1}{4}$	21	$21\frac{1}{4}$
70	$23\frac{1}{4}$	$22\frac{7}{16}$	$22\frac{3}{4}$
80	$24\frac{3}{4}$	24	$24\frac{1}{4}$
90	$26\frac{3}{4}$	$25\frac{5}{16}$	$25\frac{3}{4}$
100	$28\frac{1}{4}$	$26\frac{13}{16}$	$27\frac{1}{4}$

Note.—Dimension A is the distance from gauge side of rail to point on cover of Model 2 switch machine equal to height of rail used.

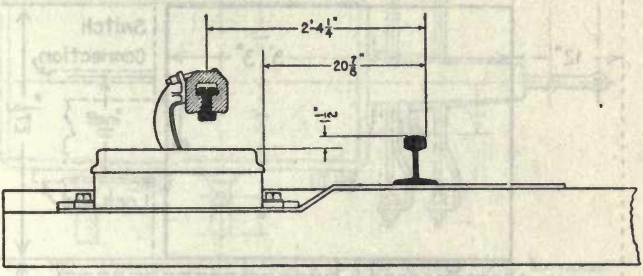


Fig. 157. Diagram Showing Clearance between Top of Model 4 Switch Machine and Contacting Surface of Third Rail. Electric Division, N. Y. C. & H. R. R. R.

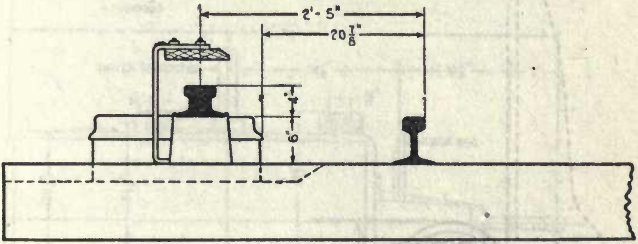


Fig. 158. Diagram Showing Clearance between Top of Model 4 Switch Machine and Contacting Surface of Third Rail, Long Island R. R.

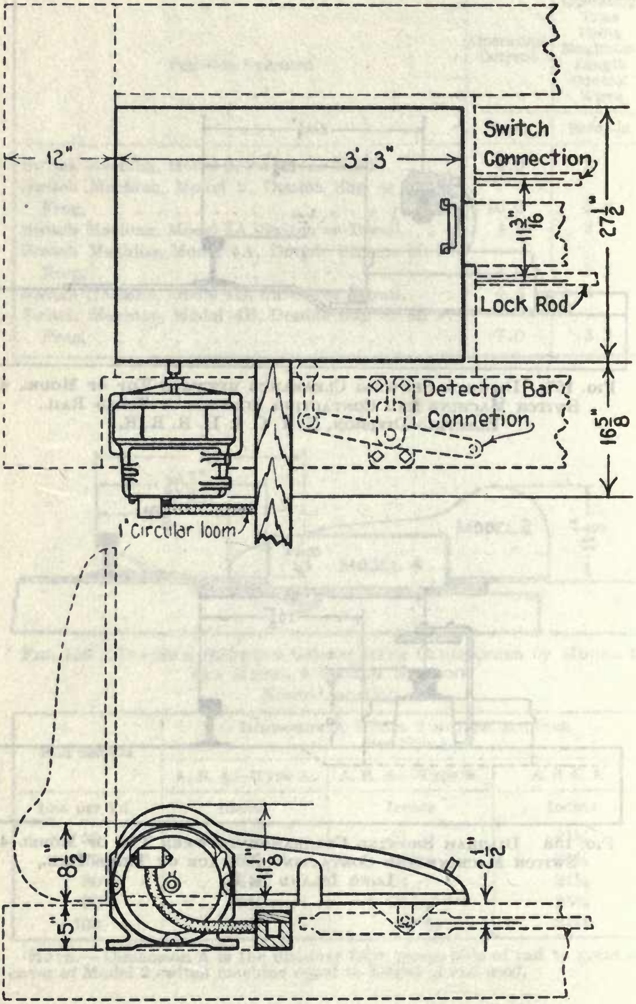


FIG. 159. DIMENSIONS OF MODEL 2 SWITCH MACHINE

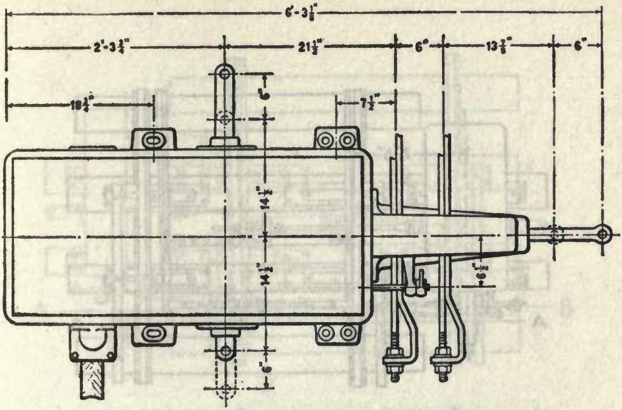


FIG. 160. DIMENSIONS OF MODEL 4 SWITCH MACHINE FOR MOVABLE POINT FROG OR DOUBLE SLIP SWITCH

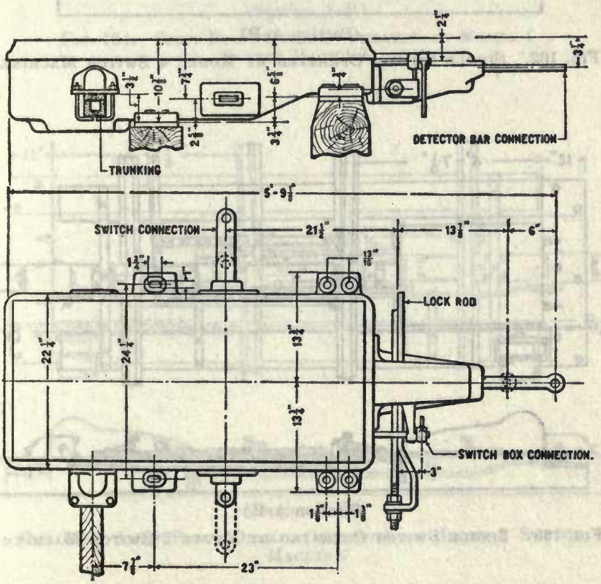
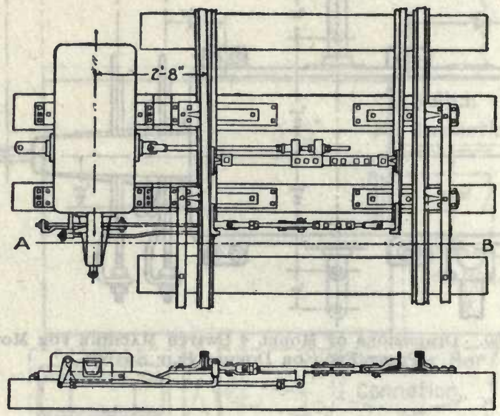
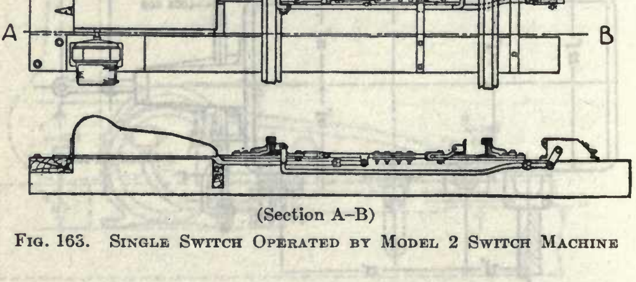


FIG. 161 DIMENSIONS OF MODEL 4 SWITCH MACHINE FOR SINGLE SWITCH OR DERAIL



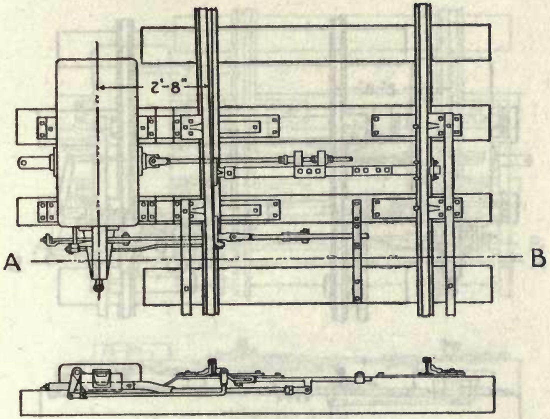
(Section A–B)

FIG. 162. SINGLE SWITCH OPERATED BY MODEL 4 SWITCH MACHINE



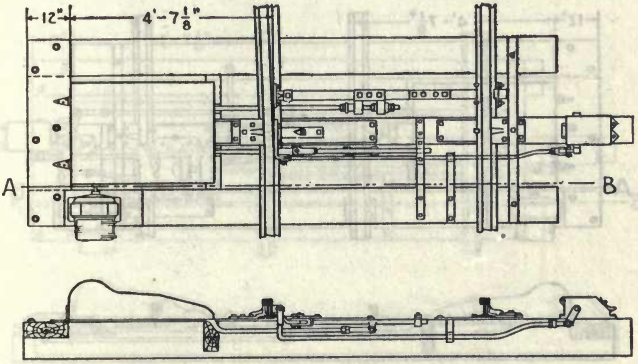
(Section A–B)

FIG. 163. SINGLE SWITCH OPERATED BY MODEL 2 SWITCH MACHINE



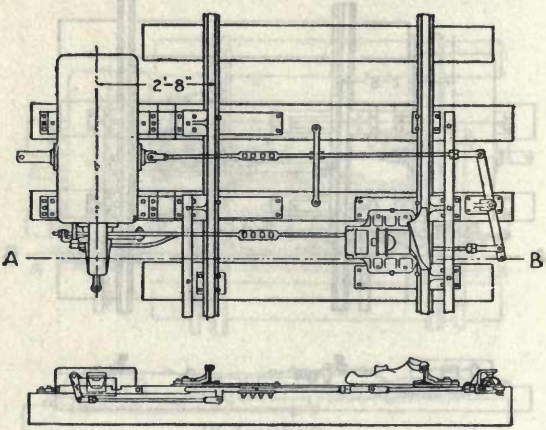
(Section A–B)

FIG. 164. SPLIT POINT DERAIL OPERATED BY MODEL 4 SWITCH MACHINE



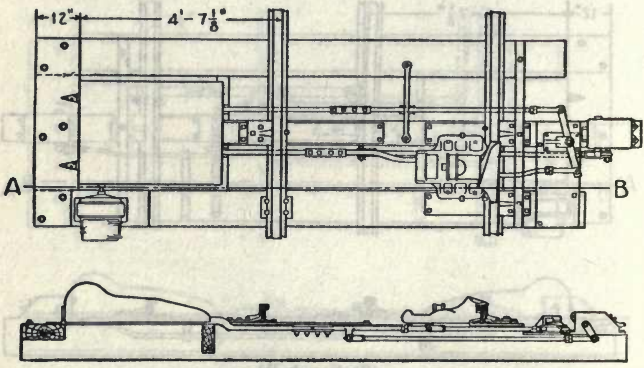
(Section A–B)

FIG. 165. SPLIT POINT DERAIL OPERATED BY MODEL 2 SWITCH MACHINE



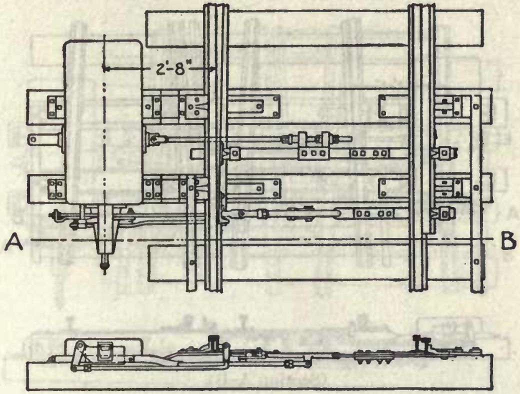
(Section A–B)

Fig. 166. Hayes Derail Operated by Model 4 Switch Machine



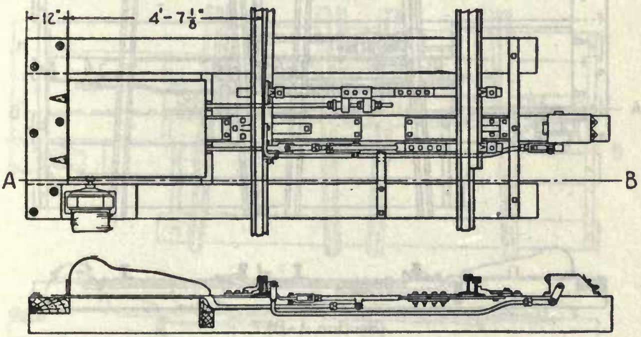
(Section A–B)

Fig. 167. Hayes Derail Operated by Model 2 Switch Machine



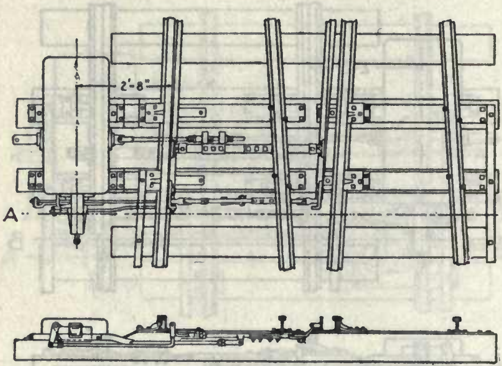
(Section A–B)

FIG. 168. WHARTON OR MORDEN DERAIL OPERATED BY MODEL 4 SWITCH MACHINE



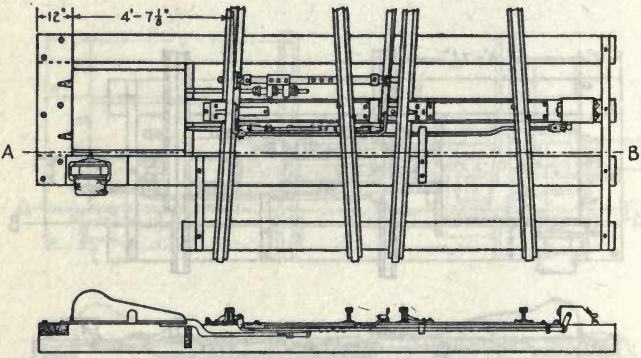
(Section A–B)

FIG. 169. WHARTON OR MORDEN DERAIL OPERATED BY MODEL 2 SWITCH MACHINE



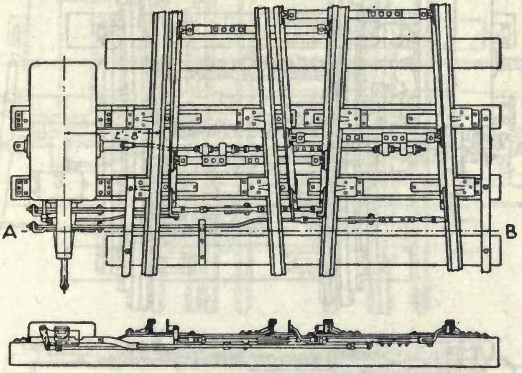
(Section A–B)

FIG. 170. SINGLE SLIP SWITCH OPERATED BY MODEL 4 SWITCH MACHINE



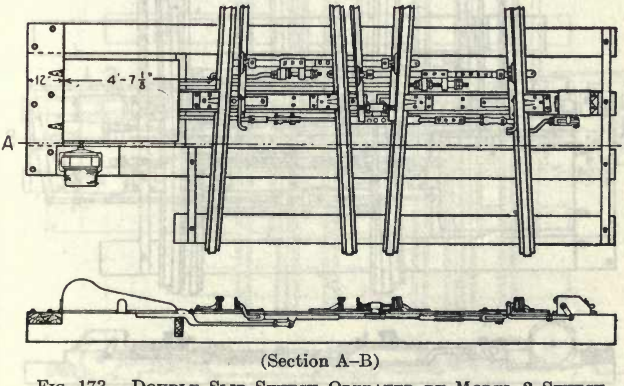
(Section A–B)

FIG. 171. SINGLE SLIP SWITCH OPERATED BY MODEL 2 SWITCH MACHINE



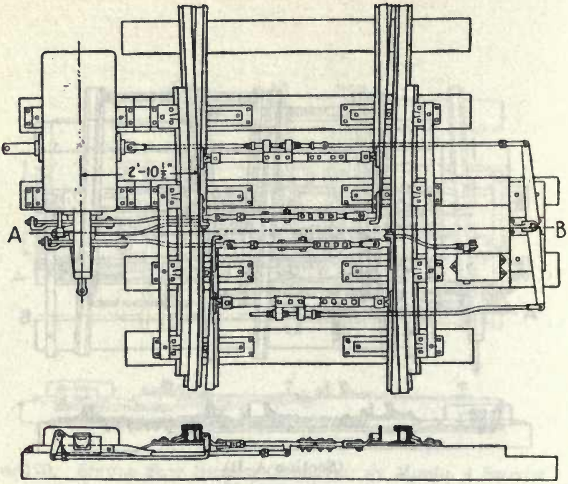
(Section A–B)

FIG. 172. DOUBLE SLIP SWITCH OPERATED BY MODEL 4 SWITCH MACHINE



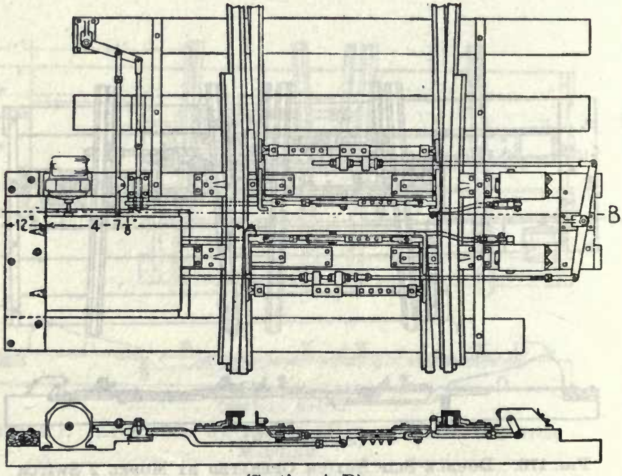
(Section A–B)

FIG. 173. DOUBLE SLIP SWITCH OPERATED BY MODEL 2 SWITCH MACHINE



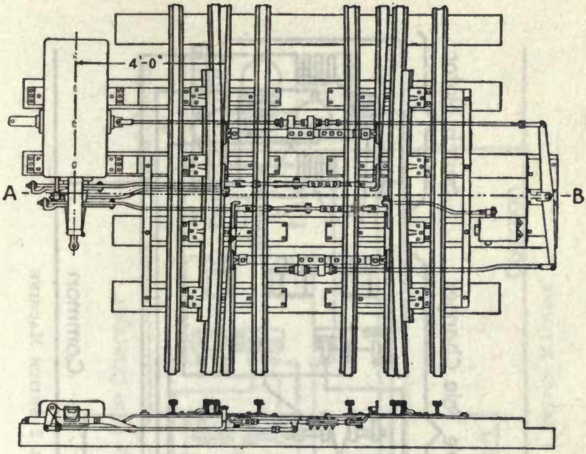
(Section A–B)

FIG. 174. MOVABLE POINT FROG OPERATED BY MODEL 4 SWITCH MACHINE



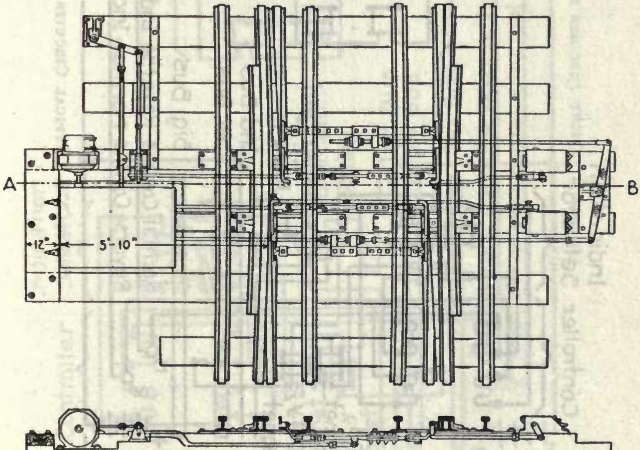
(Section A–B)

FIG. 175. MOVABLE POINT FROG OPERATED BY MODEL 2 SWITCH MACHINE



(Section A–B)

FIG. 176. MOVABLE POINT FROG (WITH DOUBLE SLIP SWITCH) OPERATED BY MODEL 4 SWITCH MACHINE



(Section A–B)

FIG. 177. MOVABLE POINT FROG (WITH DOUBLE SLIP SWITCH) OPERATED BY MODEL 2 SWITCH MACHINE

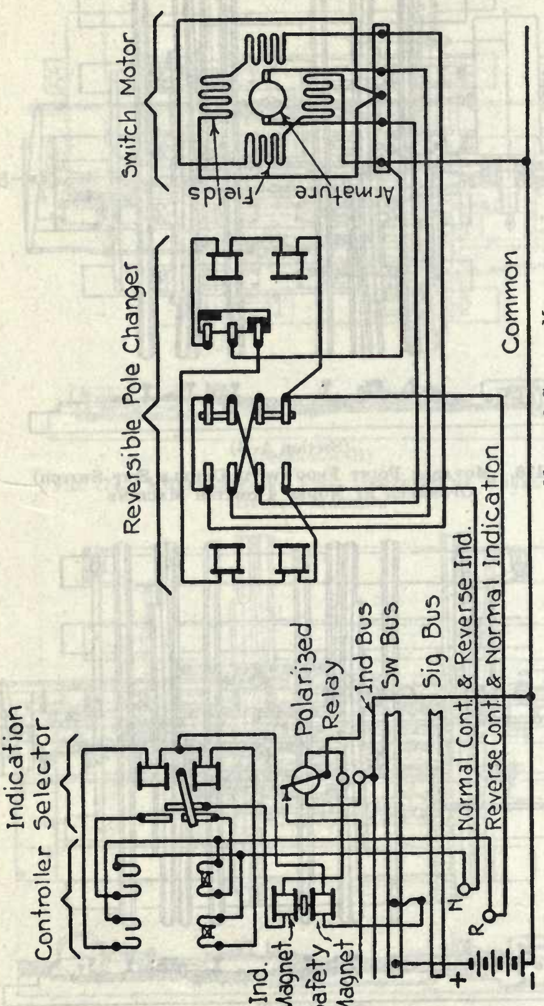


Fig. 178. Typical Circuits for Model 2 Switch Machine

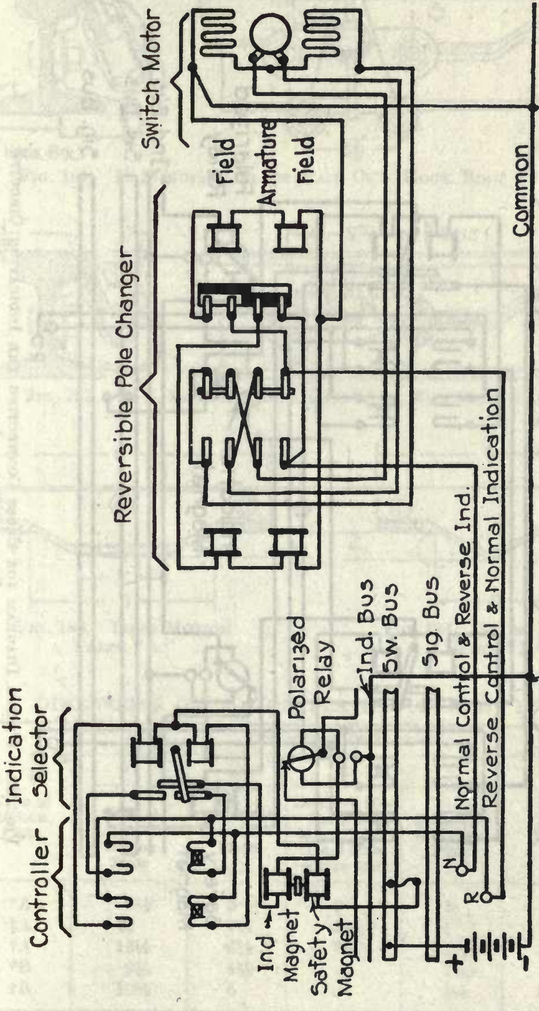


FIG. 179. TYPICAL CIRCUITS FOR MODEL 4 SWITCH MACHINE

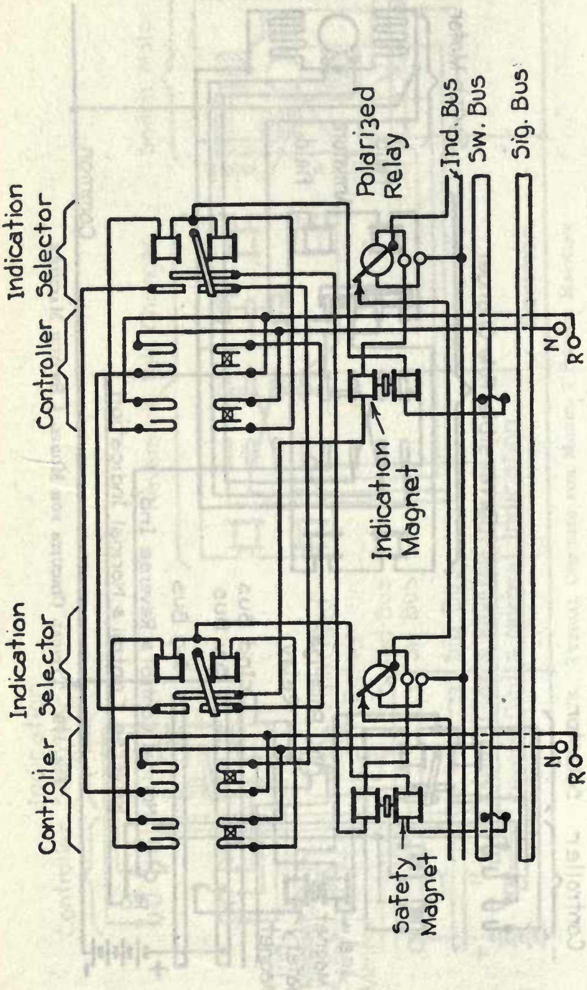


FIG. 180. WIRING DIAGRAM FOR CROSS CONNECTING THE INDICATION CIRCUITS OF DOUBLE SWITCH LEVERS

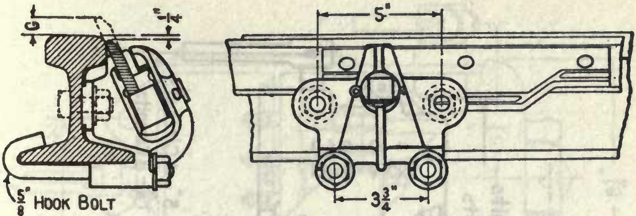


FIG. 181. E. Z. MOTION PLATE RAIL CLIP, HOOK BOLT TYPE

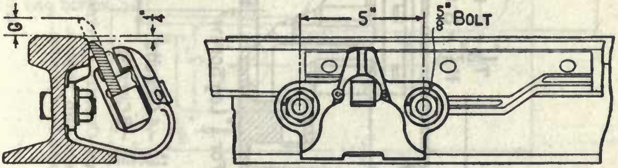


FIG. 182. E. Z. MOTION PLATE RAIL CLIP, WEB BOLT TYPE

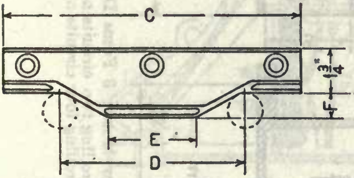


FIG. 183. LONG MOTION PLATE "A"

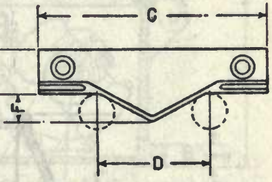


FIG. 184. SHORT MOTION PLATE "B"

DIMENSIONS OF MOTION PLATES "A" AND "B"

Type of Motion Plate	Dimensions in Inches				
	C	D	E	F	G
	Overall Length of Motion Plate	Stroke of Motion Plate	Distance Motion Plate Moves After Total Rise Above Rail	Total Rise of Motion Plate	Rise Above Rail
*A	9½	6	2	1	¾
†A	12	7⅜	3½	1	¾
†A	12½	8½	2¾	1 7/16	1 3/16
*B	9⅛	4½	..	1 5/32	29/32
†B	10½	6	..	1½	1¼

* Two rivet holes. † Three rivet holes.

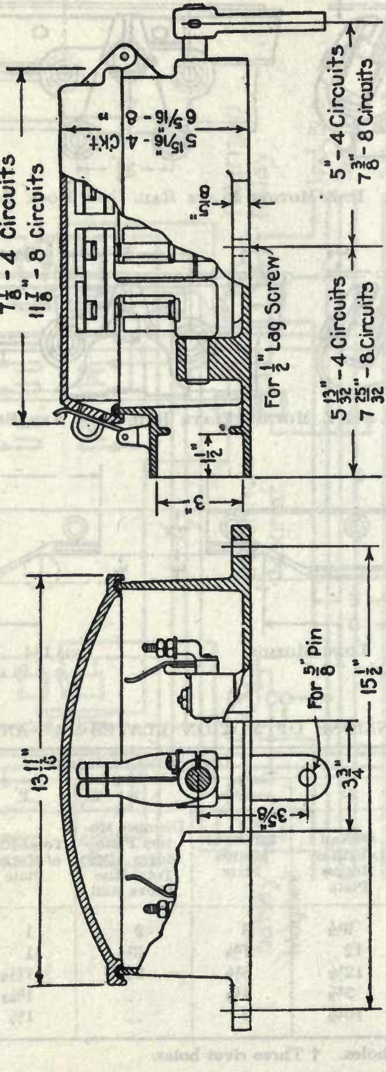


Fig. 185. Dimensions of Model 3 Form D Switch Circuit Controllers

Four way, controlling two circuits normal and two reverse.
Eight way, controlling four circuits normal and four reverse.

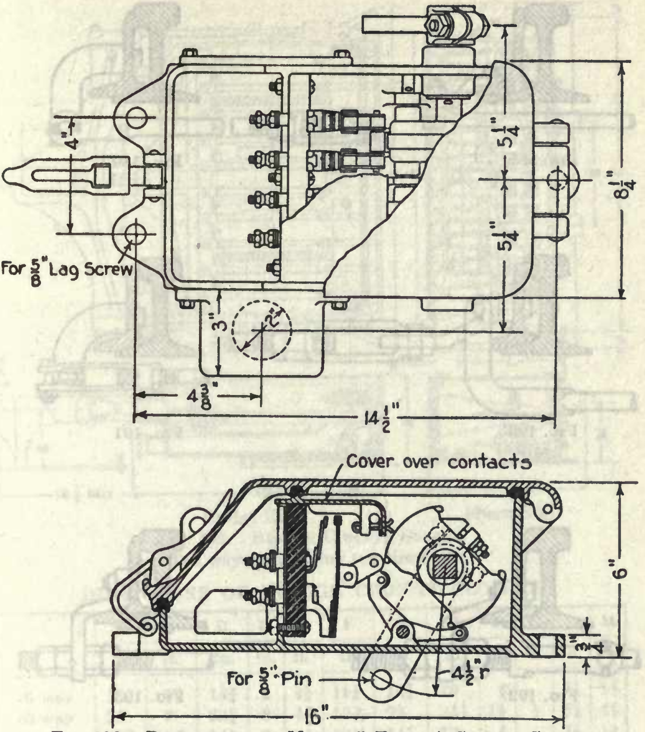


FIG. 186. DIMENSIONS OF MODEL 5 FORM A SWITCH CIRCUIT CONTROLLER FOR SELECTING SIGNAL CIRCUITS

Four circuits normal or reverse, or two circuits normal and two reverse.

FIG. 187. SECTION OF ADJUSTABLE CAM FOR MODEL 5 FORM A SWITCH CIRCUIT CONTROLLER (FIG. 186).

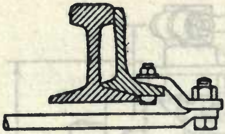


FIG. 188

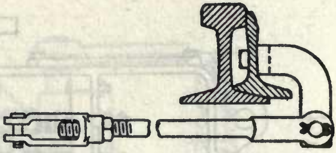


FIG. 189

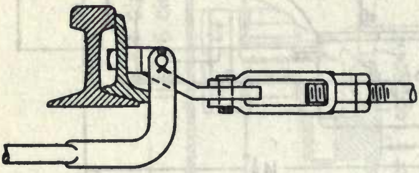


FIG. 190

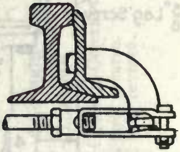


FIG. 191

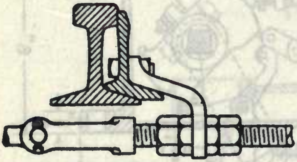


FIG. 192

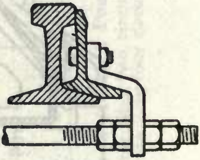


FIG. 193

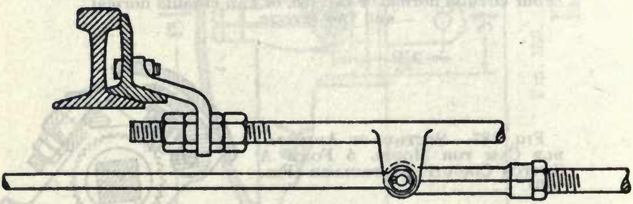
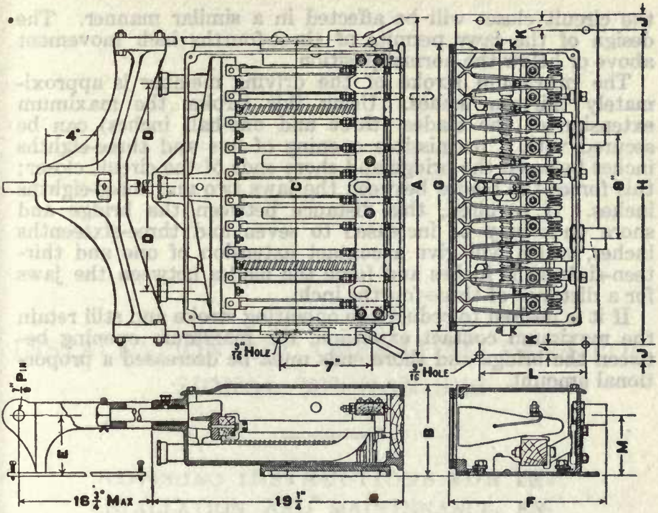


FIG. 194

CONNECTIONS FROM SWITCH POINT TO SWITCH CIRCUIT CONTROLLER



Bridge End Shore End

FIG. 195. BRIDGE CIRCUIT CLOSER
Ten way, controlling ten circuits.

DIMENSIONS OF BRIDGE CIRCUIT CLOSERS

	A	B	C	D	E	F	G	H	J	K	L	M
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
6 way	$18\frac{7}{8}$	$6\frac{5}{8}$	$14\frac{3}{4}$	2	$4\frac{1}{8}$	$11\frac{1}{4}$	$14\frac{7}{8}$	19	$\frac{5}{8}$	..	$7\frac{1}{2}$	$1\frac{5}{8}$
10 way	26	7	$22\frac{3}{4}$	8	$4\frac{9}{16}$	$12\frac{3}{16}$	22	$24\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	$8\frac{1}{8}$	$4\frac{3}{4}$
12 way	$18\frac{7}{8}$	$11\frac{5}{16}$	$14\frac{3}{4}$	2	$4\frac{1}{8}$	$10\frac{15}{16}$	$14\frac{7}{8}$	19	$\frac{5}{8}$	..	$7\frac{1}{2}$	$1\frac{3}{8}$

NOTE.—Twelve way circuit closer is furnished with two tiers of six contacts each.

OPERATION OF BRIDGE CIRCUIT CLOSER

The G. R. S. bridge circuit closer with centering device is shown in Fig. 195. In the operation of closing, the bridge end is first caused to approach the shore end with its centering arms thrust forward. When these come into contact with the shore end, the latter is brought into proper alignment, the bridge end continuing its forward movement until they abut; the blades are then forced to enter the jaws, thus making the desired contact.

The centering device will take care of any horizontal misalignment up to one and one-half inches. When this is apt to be exceeded, the circuit closer should be attached to the rails in such a manner that when the rails are lined up the circuit closer will be affected in a similar manner. The design of the jaws permits of three-fourths inch movement above or below the normal position.

The maximum stroke of the driving member is approximately thirteen inches. Using this stroke, the maximum extension of the blades (three and one-half inches) can be secured with a permissible opening of five and three-eighths inches between the bridge and shore ends of the circuit closer; this forces the blades between the jaws two and three-eighths inches. If required, this distance between the bridge and shore ends may be increased to seven and three-sixteenths inches, which will give a contact extension of one and thirteen-sixteenths inches and force the blades between the jaws for a distance of three-fourths inch.

If it is desired to reduce the operating stroke and still retain the maximum contact extension, the maximum opening between the bridge and shore ends must be decreased a proportional amount.

SECTION IX

INSTALLATION AND OPERATING DATA FOR SIGNAL MECHANISMS

COVERING INSTRUCTIONS FOR INSTALLATION AND MAINTENANCE, ENERGY FIGURES, CLEARANCES REQUIRED, DIMENSIONS AND TYPICAL CIRCUITS; ALSO DIMENSIONS OF MASTS, SPECTACLES, BLADES AND FOUNDATIONS

INSTRUCTIONS COVERING THE INSTALLATION AND MAINTENANCE OF MODEL 2A SIGNALS

Storing Mechanisms

ALL mechanisms should be stored in an upright position and, if possible, in a dry place, and should not be removed from their boxes until they are installed. Avoid disconnecting or removing the motors from the mechanism cases.

Installation

In assemblying mechanisms which are shipped separately from the pole bearings or in reassemblying mechanisms which have been disassembled for any purpose, the surface of all exposed mechanical joints must be cleaned and smoothly coated with white lead before assembly, to insure that they are water-tight.

Whenever it becomes necessary to bolt a mechanism to its pole bearing, see that the semaphore shaft and mechanism are approximately in their "stop" positions. Then rotate the semaphore shaft backwards and forwards slightly by hand while tightening the bolts, to be sure that no binding takes place during the process.

When working on a mechanism, the motor door should always be kept closed except when necessary to do work inside of the motor.

After a mechanism has been wired, the wire entrance should be sealed to prevent the circulation of air between the inside and outside of the case. Neglect to thoroughly seal may result in trouble due to the probable accumulation of frost or dirt on the circuit breaker parts. If conduit is used between the mechanism case and the pole, the wire entrance or conduit should be likewise sealed.

Adjustments

All signals are properly adjusted before shipment, the only adjustments ordinarily required in the field being those due to differences in the semaphore spectacles as follows: if the blade is not horizontal when in its stop position, it can be brought to such position by means of adjusting screw A (see Fig. 197). Spring C, adjusted by screw D, should hold block B firmly against screw A, due allowance being made in the spring adjustment for any increase in weight of the signal arm, due to an accumulation of ice or sleet. Fig. 197 shows relation of adjusting screws, spring, block, etc., when used with upper quadrant signals; this will be reversed when applied to lower quadrant signals.

Having adjusted the blade to the horizontal position, the circuit breaker frame should, if necessary, be rotated bodily

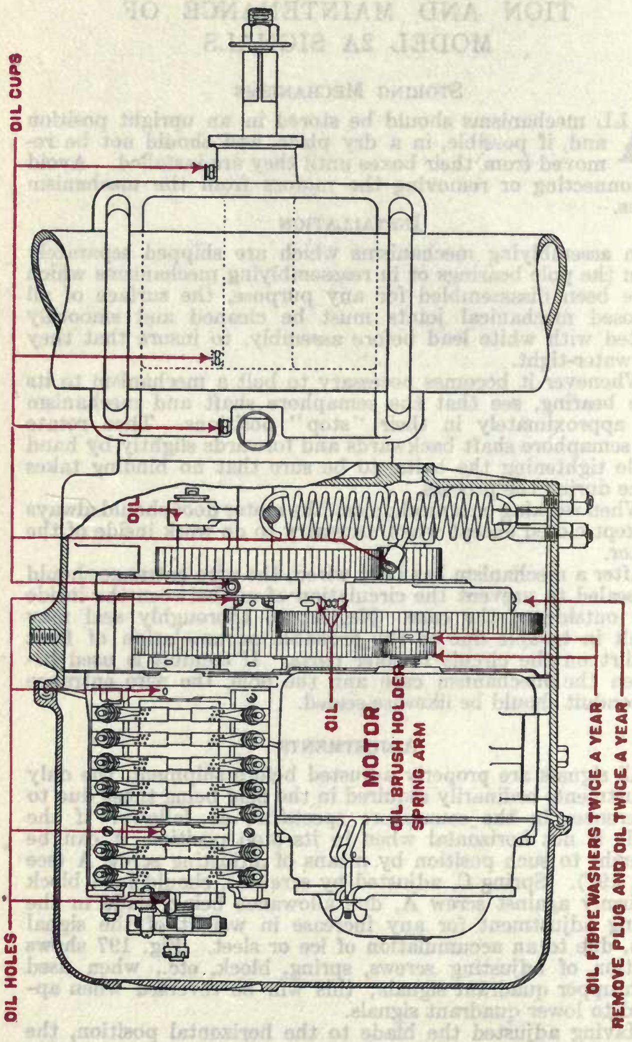


Fig. 196. Oiling Diagram for Model 2A Semi-Automatic Signal Mechanism and Clamp Bearing

a sufficient amount to cause the blade to assume its exact forty-five or ninety degree position in operation.

Individual adjustment of the circuit breaker contact springs should not be necessary under ordinary conditions. If required, great care should be exercised to see that all contacts are adjusted to open and close as shown on the circuit plan which accompanies each signal mechanism.

In replacing a circuit breaker which may have been removed from the mechanism for any cause, great care should be taken to see that the circuit breaker operating segments mesh properly. Otherwise, it will be impossible for the blade to assume

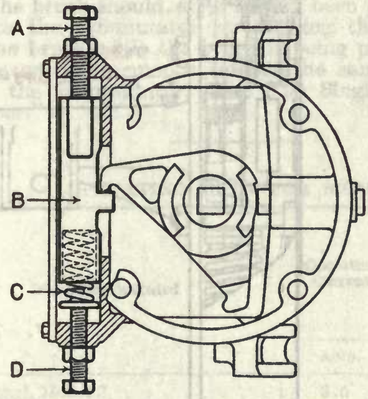


Fig. 197. Section of Clamp Bearing Showing Semaphore Spectacle Adjustment

its proper positions in operation except by extreme adjustment of the contacts and circuit breaker.

Lubrication

See that all moving parts are thoroughly lubricated with oil that will not thicken in cold weather or dry up in hot weather. "Hydrol," "Polar Ice," or "3 in One" oils have been found satisfactory. Use an oil can with a nine inch curved spout.

After lubrication, the signals should be operated several times, in order to work the oil thoroughly into the bearings. The word "oil" on the diagram, Fig. 196, will indicate what parts require lubrication. If the mechanism has become rusty, especial care should be taken to see that all parts are operating freely before attempting to put the signal in service.

Tests

If the signal has been properly adjusted and lubricated it will operate freely. If in doubt as to whether a signal is sufficiently free in operation, a drop-away test should be made as follows. Connect an adjustable resistance in series with the motor. Gradually reduce it until the motor will just move the blade upwards. Just before reaching the forty-five degree position, quickly insert sufficient resistance to just

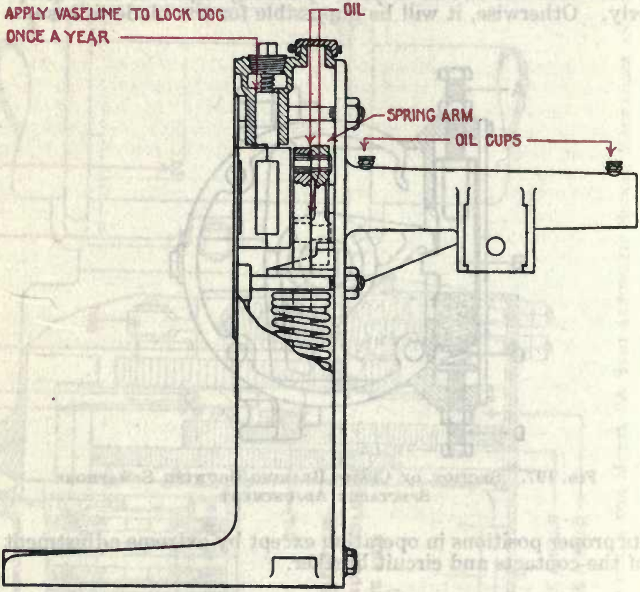


Fig. 198. Oiling Diagram for Model 2A Dwarf Bearing

permit the motor to start backwards, moved by the weight of the blade grip. The current which will permit it to start backwards from a given position should be approximately 50 per cent. of the current required to move it up to that position. The same process should be repeated in the ninety degree position or sixty degree, as the case may be.

The signal having been oiled and operated a few times, see that the blade snubs properly in descending and also that the ratcheted main gear (F, Figs. 52 and 56) clicks approximately three or four times in so doing. The number of clicks can be regulated by the adjusting screw on the ratcheted main gear.

Maintenance

Ordinarily in maintaining a signal, the only requirements are that the connections be kept tight, contacts clean, and the mechanism suitably oiled and cleaned.

Avoid disturbing the commutator or brushes in any way unless found necessary. A commutator in good condition will have a dark glossy appearance. If, however, it should become dirty, it should be cleaned by chamois skin moistened with oil, any surplus oil to be wiped off of the commutator by a dry piece of chamois.

Use a chamois skin in cleaning the circuit breaker contacts.

If it should become necessary to put a new brush into a motor, the brush should, after having been put in position, be seated to the commutator by drawing thin fine sandpaper under the brush while the brush is being pressed against the commutator. The smooth side of the sandpaper should be against the commutator. Use "00 Single Finishing Flint Sandpaper."

OPERATING DATA FOR SIGNALS

Function Operated	Operating Current	Holding Current	Operating Time Using Maximum Length Control Wire
	Amp.	Amp.	Seconds
High Signal, Model 2, ...	3.0	.14	4
High Signal, Model 3 or 7, ...	3.0	.11	3
High Signal, Model 2A, ...	.82	.25	6
Dwarf Signal, Model 2A, ...	.82	.25	4
Dwarf Signal, Model 2 or 3, ...	4.0	.17	1

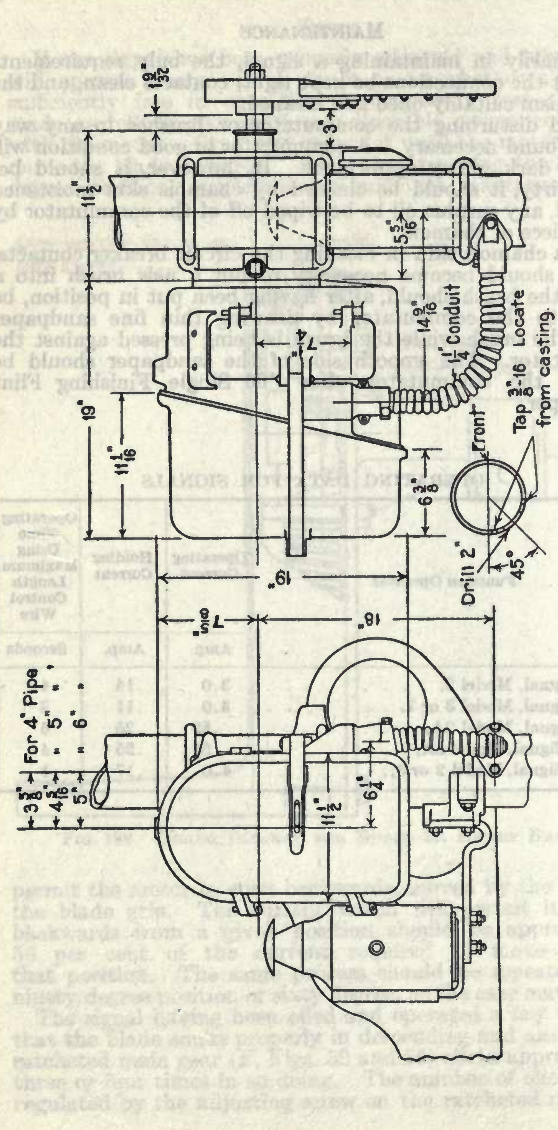


FIG. 199. DIMENSIONS OF MODEL 2A SEMI-AUTOMATIC SIGNAL
Wires carried from mast to signal mechanism in flexible conduit (see Fig. 203).

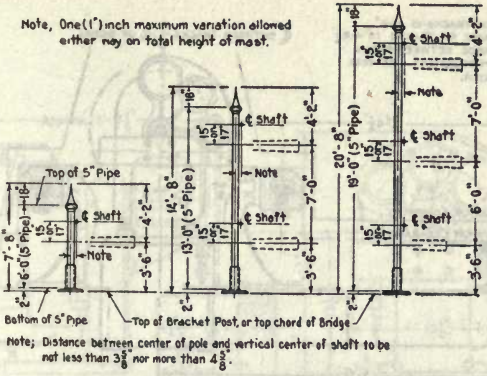


FIG. 200. BRACKET POST AND BRIDGE SIGNAL MASTS
R. S. A. drawing 1037, dated 1910.

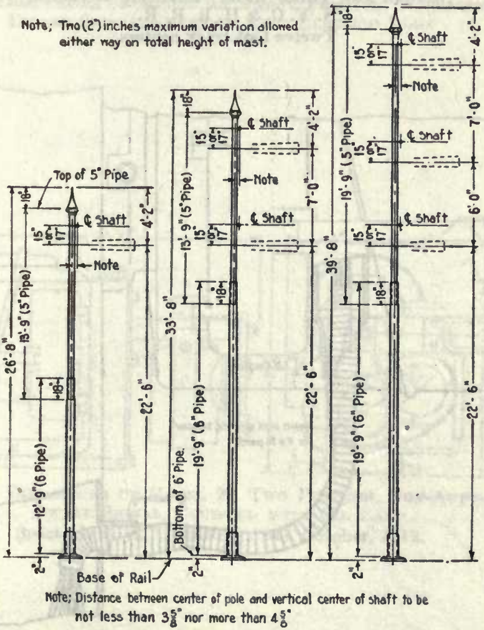


FIG. 201. GROUND SIGNAL MASTS
R. S. A. drawing 1035, dated 1910.

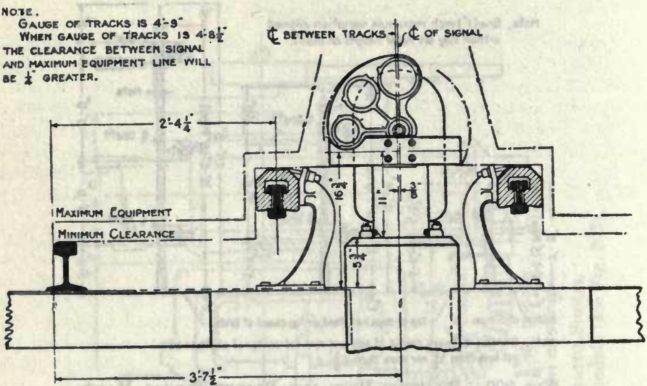


FIG. 202. DIAGRAM SHOWING CLEARANCE BETWEEN MODEL 2A DWARF SIGNAL AND THIRD RAIL. ELECTRIC DIVISION, N. Y. C. & H. R. R. R.
Twelve foot track centers.

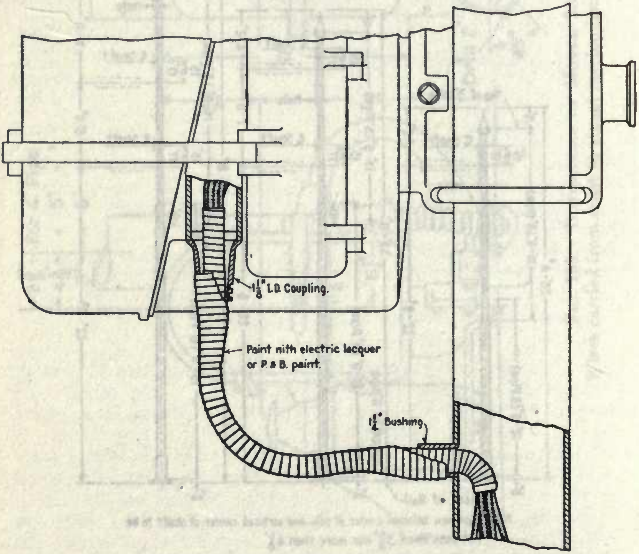


FIG. 203. METHOD OF TAPING WIRES RUNNING FROM MAST TO SIGNAL MECHANISM (see Fig. 199)

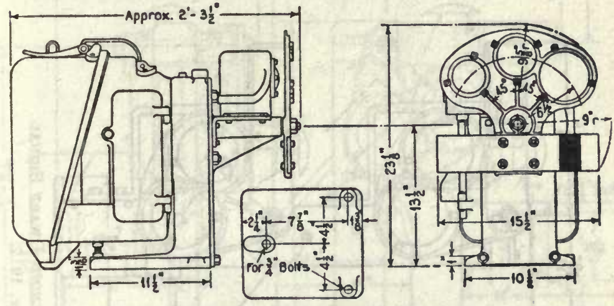


FIG. 204. DIMENSIONS OF MODEL 2A THREE POSITION, NON-AUTOMATIC DWARF SIGNAL, EQUIPPED WITH ELECTRIC LAMP

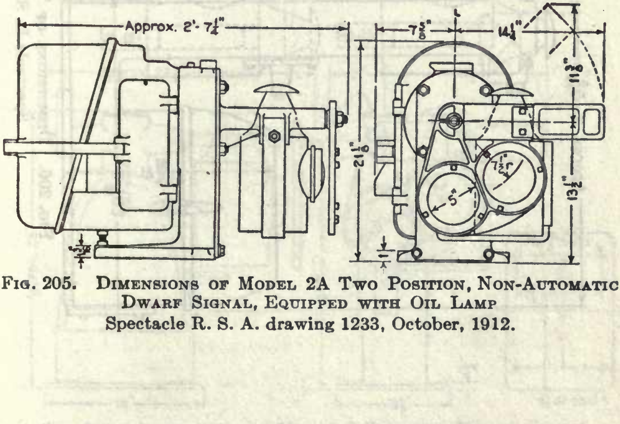


FIG. 205. DIMENSIONS OF MODEL 2A TWO POSITION, NON-AUTOMATIC DWARF SIGNAL, EQUIPPED WITH OIL LAMP
Spectacle R. S. A. drawing 1233, October, 1912.

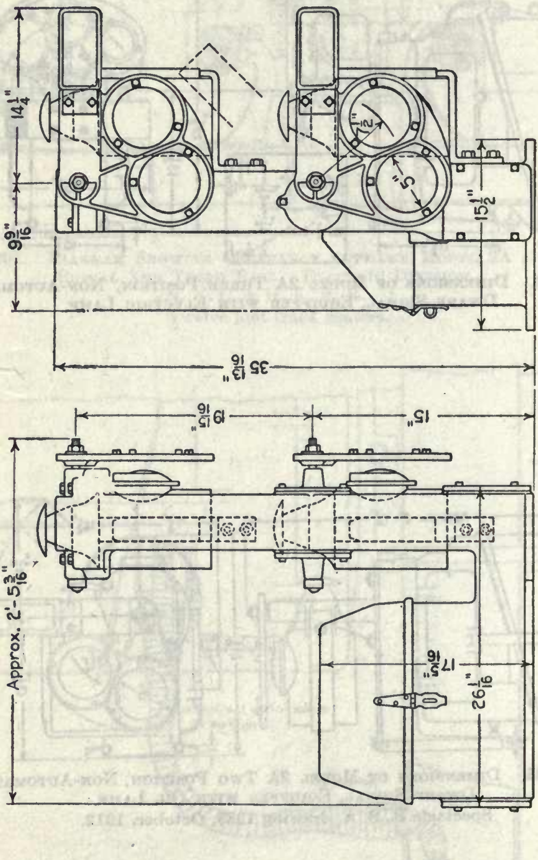


FIG. 206. DIMENSIONS OF TWO ARM MODEL 2 SOLENOID DWARF SIGNAL
Spectacle R. S. A. drawing 1233, October, 1912.

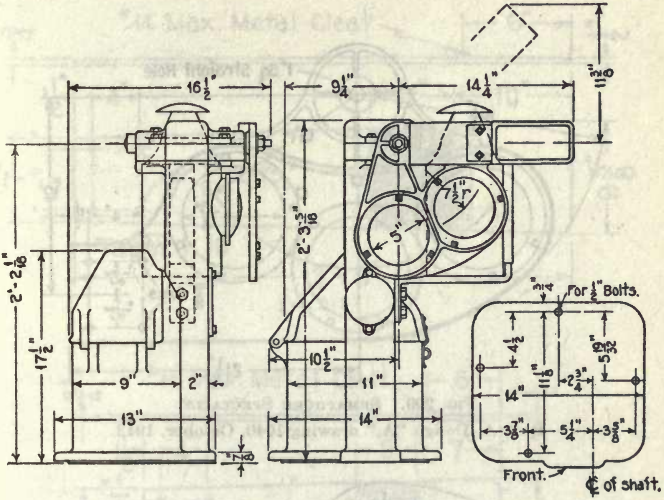


Fig. 207. Dimensions of One Arm Model 2 Solenoid Dwarf Signal
Spectacle R. S. A. drawing 1233, October, 1912.

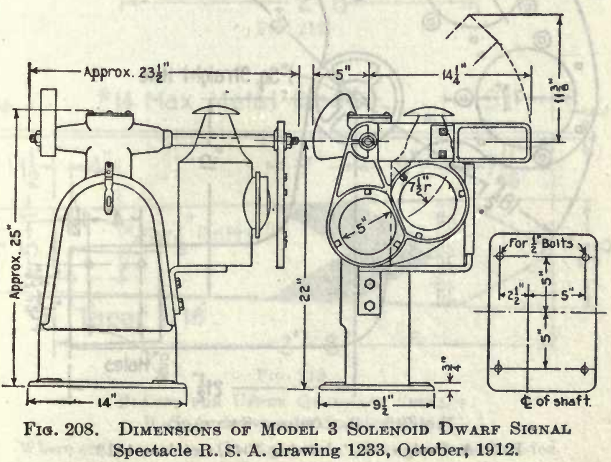


Fig. 208. Dimensions of Model 3 Solenoid Dwarf Signal
Spectacle R. S. A. drawing 1233, October, 1912.

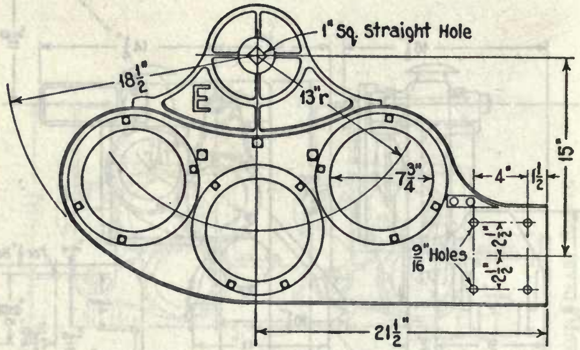


FIG. 209. SEMAPHORE SPECTACLE
R. S. A. Design "A," drawing 1040, October, 1912.

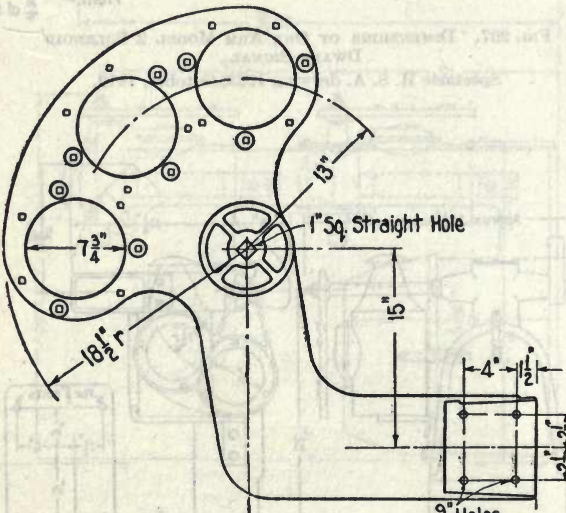


FIG. 210. SEMAPHORE SPECTACLE
R. S. A. Design "B," drawing 1041, October, 1912.

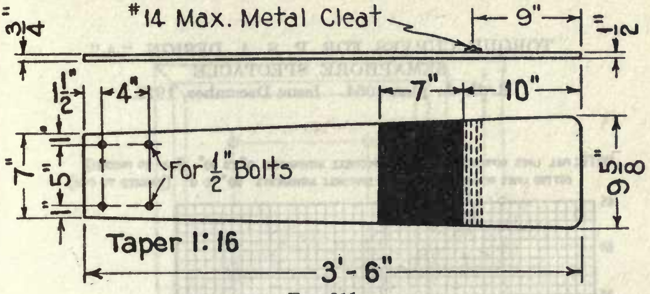


FIG. 211

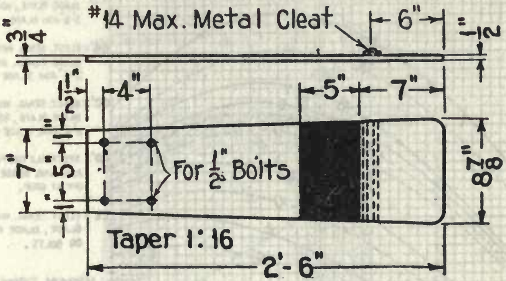


FIG. 212

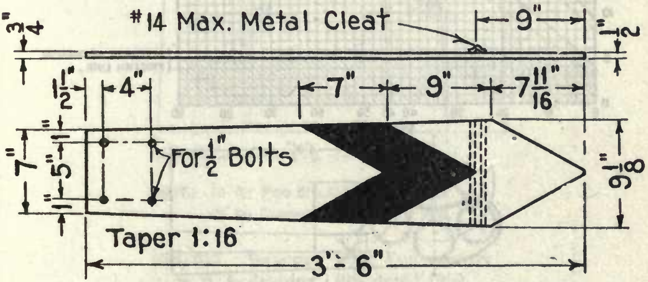


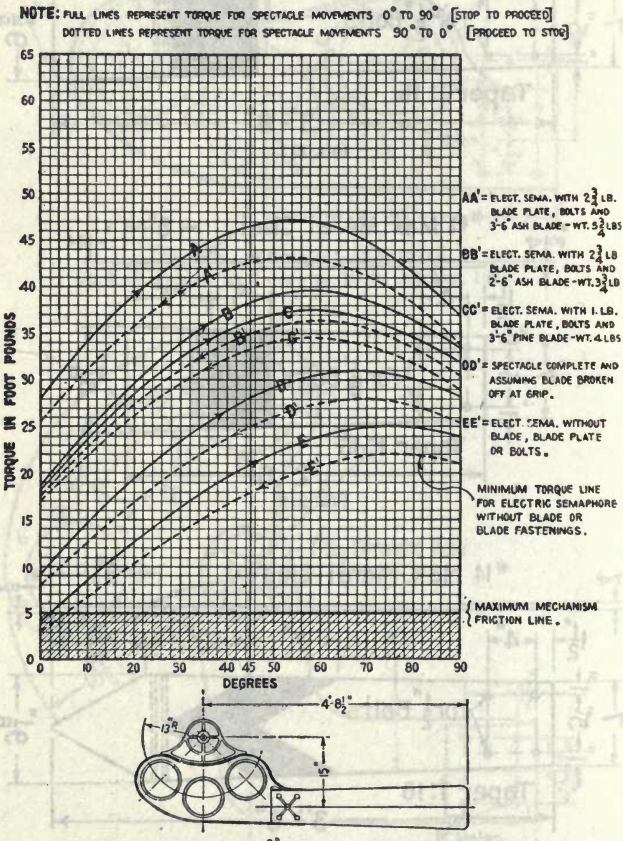
FIG. 213

BLADES FOR UPPER QUADRANT SIGNALS
R. S. A. drawing 1065, dated 1911.

Where stripes are used the dimensions shown are recommended.

TORQUE CURVES FOR R. S. A. DESIGN "A" SEMAPHORE SPECTACLE

R. S. A. plan 1064. Issue December, 1912.



NOTE: SPECTACLE EQUIPPED WITH 8 3/8" ROUNDELS AND RETAINING RINGS IN ALL CASES.

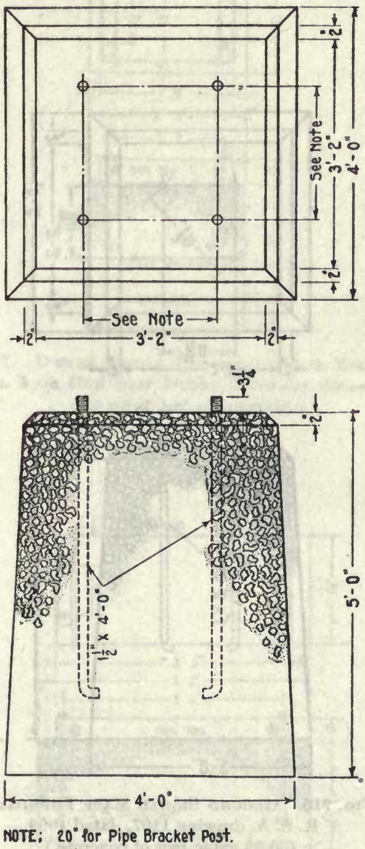


FIG. 215. BRACKET POST FOUNDATION
R. S. A. drawing 1108, dated 1909.
(70.3 cubic feet of concrete.)

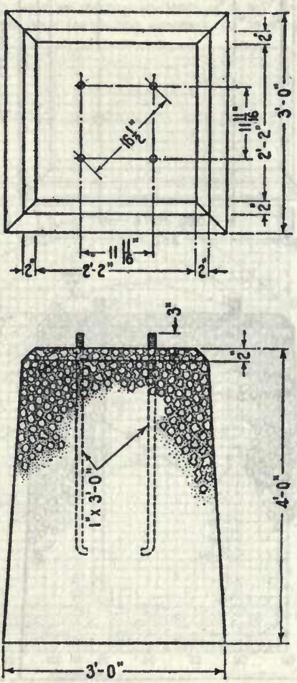


FIG. 216. GROUND SIGNAL MAST FOUNDATION
R. S. A. drawing 1107, dated 1909.
(30.25 cubic feet of concrete.)

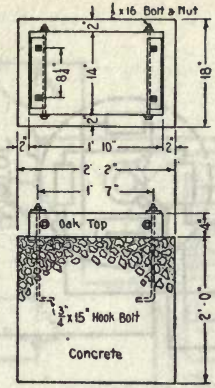


FIG. 217. DWARF SIGNAL FOUNDATION FOR MODEL 2A, MODEL 3 OR ONE ARM MODEL 2 DWARF SIGNAL
(6.5 cubic feet of concrete.)

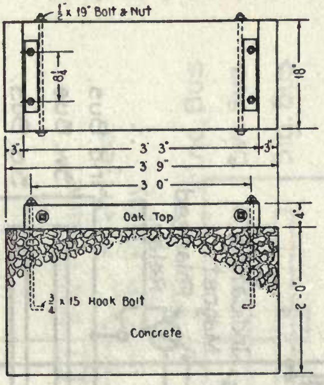


FIG. 218. DWARF SIGNAL FOUNDATION FOR TWO ARM MODEL 2 DWARF SIGNAL
(11.25 cubic feet of concrete.)

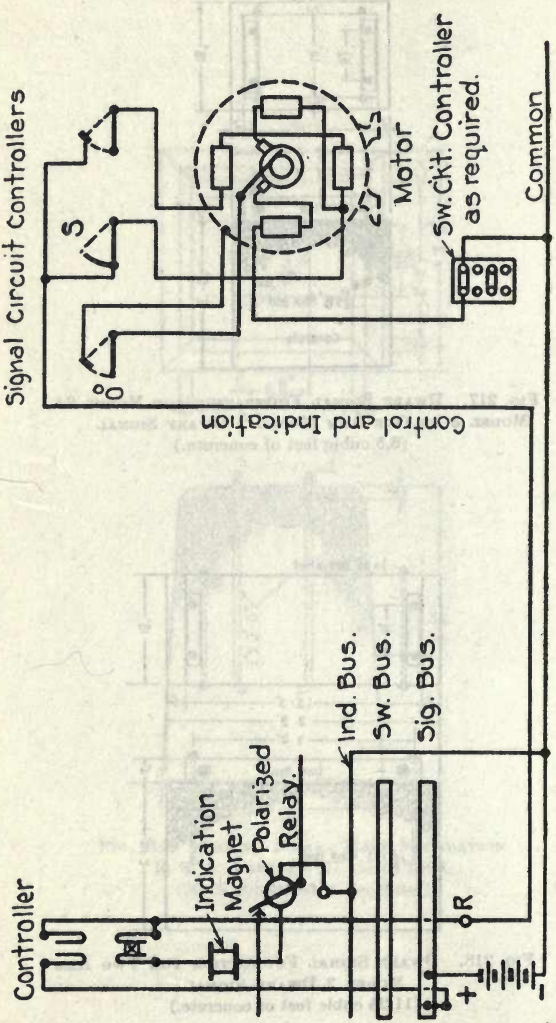


FIG. 219. TYPICAL CIRCUIT FOR MODEL 2A SIGNAL, TWO POSITION, NON-AUTOMATIC

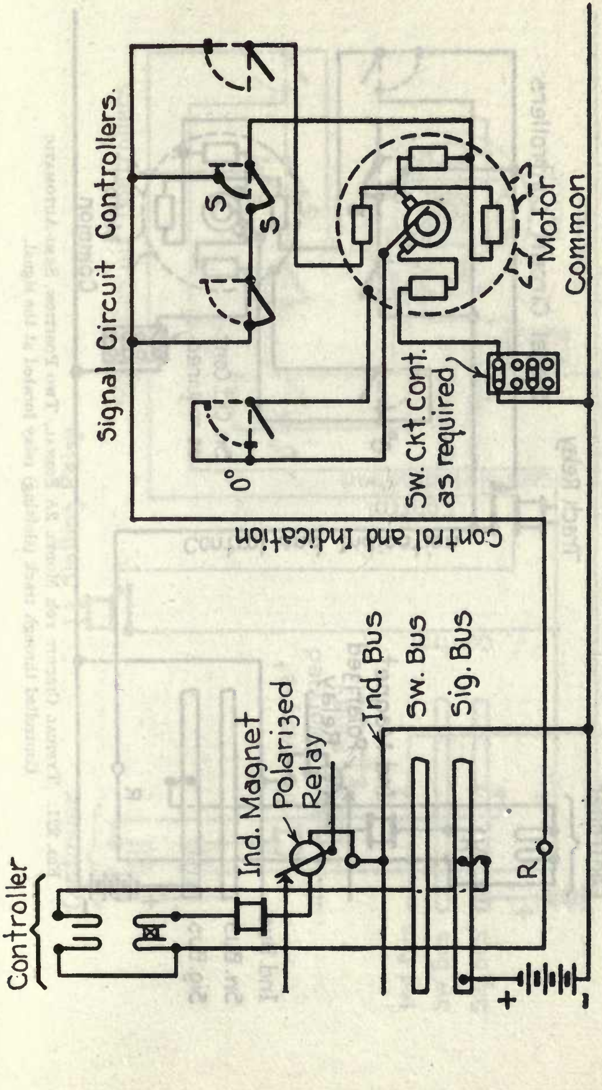


FIG. 220. TYPICAL CIRCUIT FOR MODEL 2A SIGNAL, TWO POSITION, NON-AUTOMATIC
Employing semi-automatic mechanism.

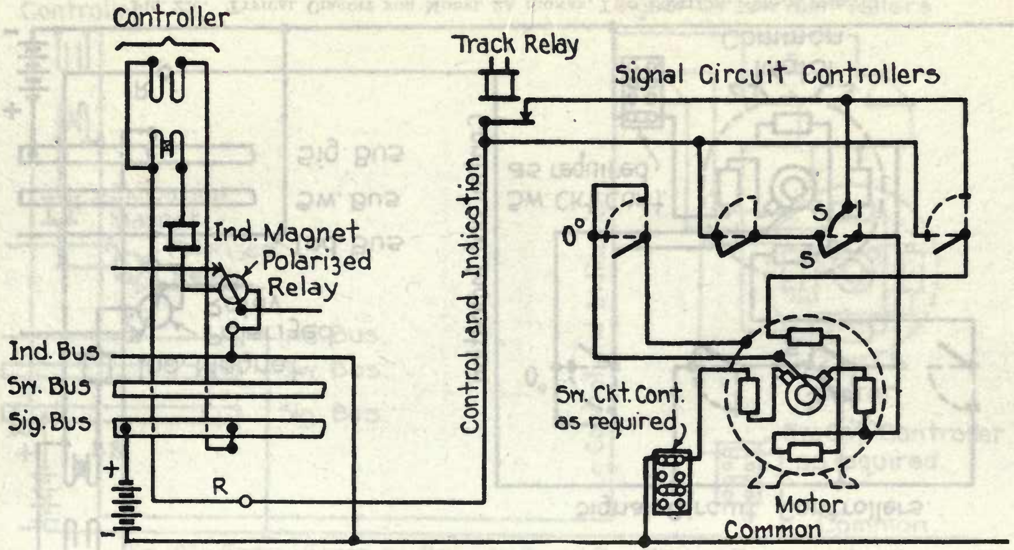


FIG. 221. TYPICAL CIRCUIT FOR MODEL 2A SIGNAL, TWO POSITION, SEMI-AUTOMATIC Controlled through track (slotting) relay located at the signal.

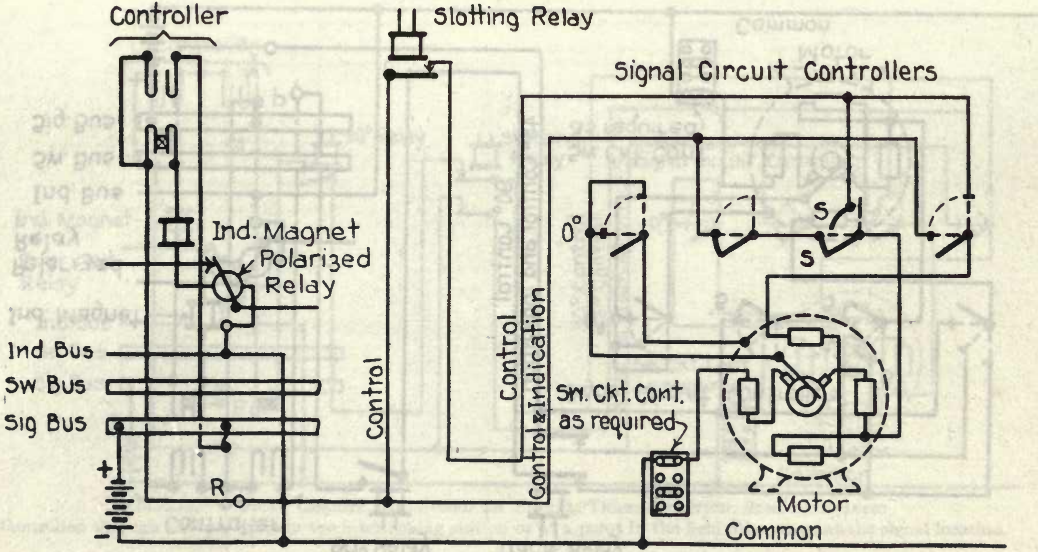


Fig. 222. Typical Circuit for Model 2A Signal, Two Position, Semi-Automatic
Controlled through slotting relay in the interlocking station or at point in the field other than at the signal location.

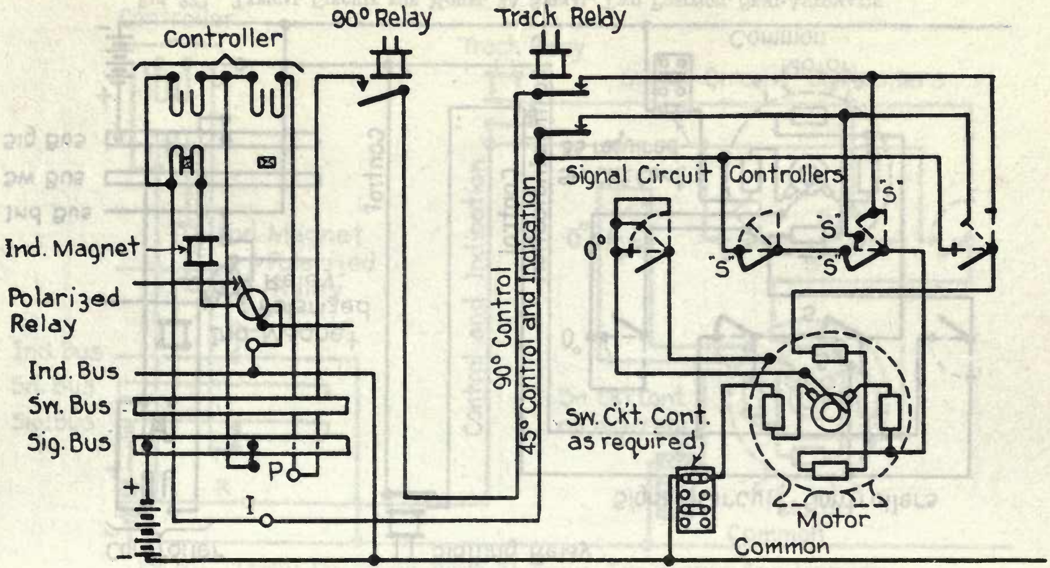


FIG. 223. TYPICAL CIRCUIT FOR MODEL 2A SIGNAL, THREE POSITION, SEMI-AUTOMATIC Controlled through track (slotting) relay located at the signal.

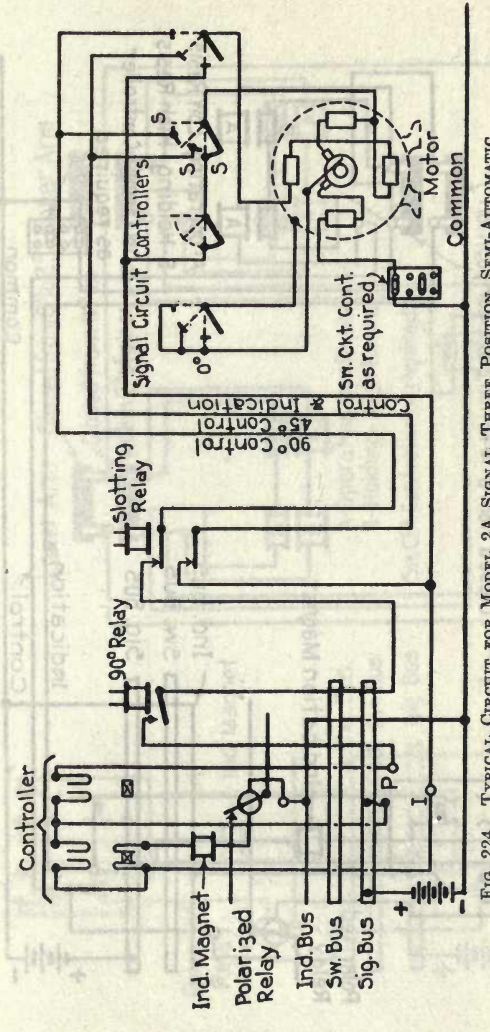


FIG. 224. TYPICAL CIRCUIT FOR MODEL 2A SIGNAL, THREE POSITION, SEMI-AUTOMATIC
Controlled through slotting relay in the interlocking station or at a point in the field other than at the signal location.

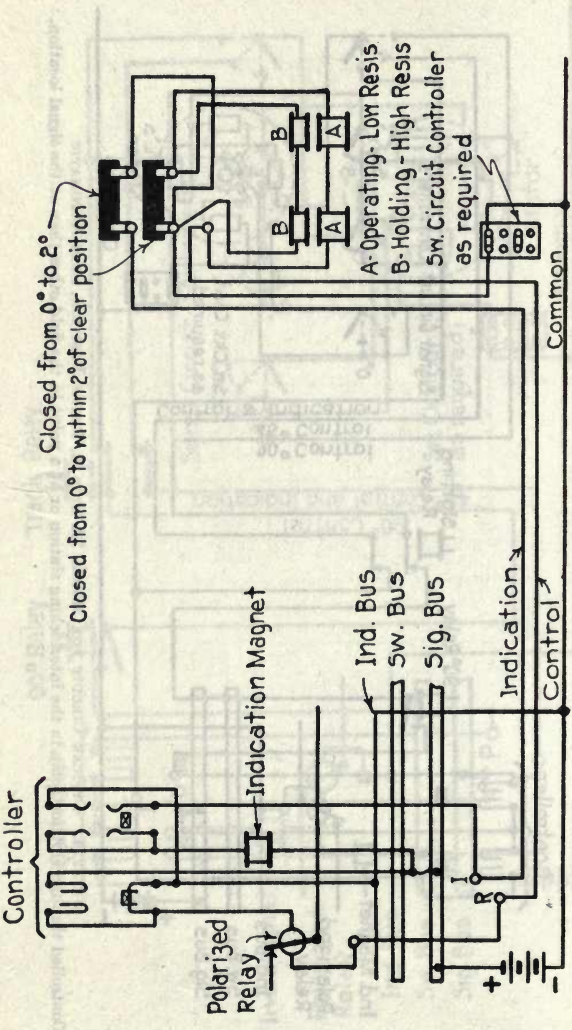


FIG. 225. TYPICAL CIRCUIT FOR ONE ARM, MODEL 2 SOLENOID DWARF SIGNAL

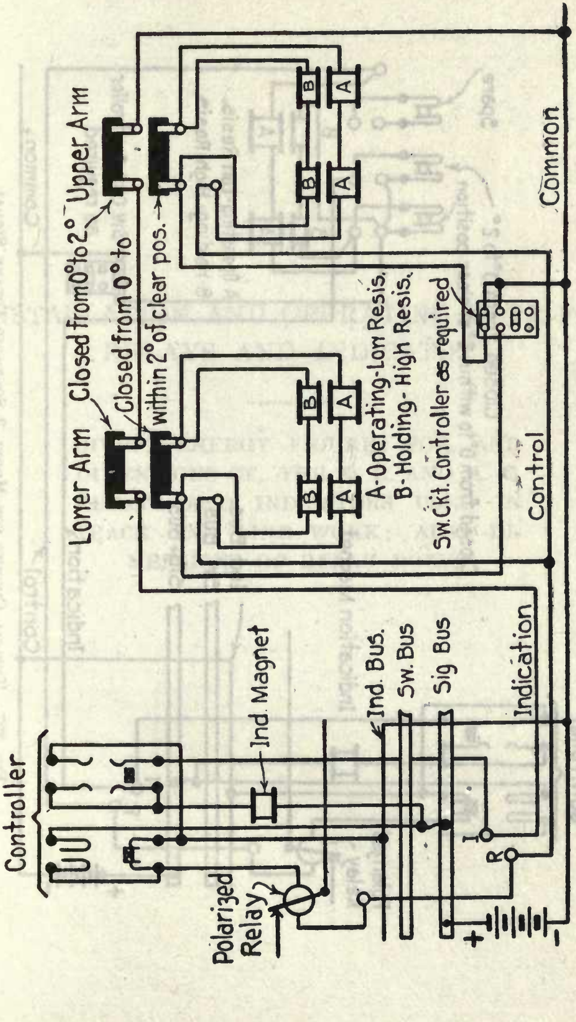


FIG. 226. TYPICAL CIRCUIT FOR TWO ARM, MODEL 2 SOLENOID DWARF SIGNAL

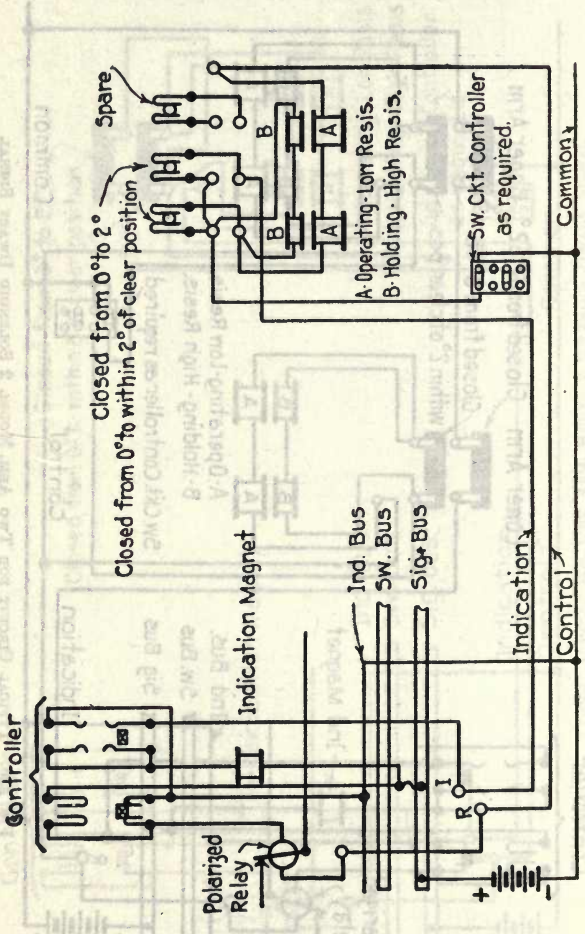


FIG. 227. TYPICAL CIRCUIT FOR MODEL 3 SOLENOID DWARF SIGNAL

INSTALLATION AND OPERATING DATA FOR RELAYS AND INDICATORS

GIVING ENERGY FIGURES FOR, AND DIMENSIONS OF, THE D. C. AND A. C. RELAYS AND INDICATORS USED IN TRACK AND LINE WORK; ALSO DIMENSIONS OF RELAY BOXES

RELAYS AND INDICATORS

ENERGY DATA FOR MODEL 1, D.C. RELAYS

Resistance Ohms	Mil. Amps.	Volts
4	110	.425
5	98	.475
9	80	.7
16	62	1.0
25	52	1.275
30	47	1.4
35	44	1.5
50	35	1.8
100	26	2.5
300	15.5	4.5
500	13	6.5
800	11	9.0
1000	10.5	10.5

NOTE.—Values given in above table are the mimimum on which the relay will operate. Add 10 per cent. for practical operation. Drop away current equals 23 per cent. of minimum operating current.

ENERGY DATA FOR STYLE A, D.C. INDICATORS

FOUR WAY.

Resistance Ohms	Mil. Amps.	Volts
4	147	.59
5	135	.675
12	97	1.16
38	56	2.13
50	49	2.45
75	41	3.10
100	37	3.70
200	31	6.20
250	27	6.75
500	18	9.00
1000	14	14.00

NOTE.— Values given in above table are the minimum on which the indicator will operate. Add 10 per cent. for practical operation. Drop away current equals 33 per cent. of minimum operating current.

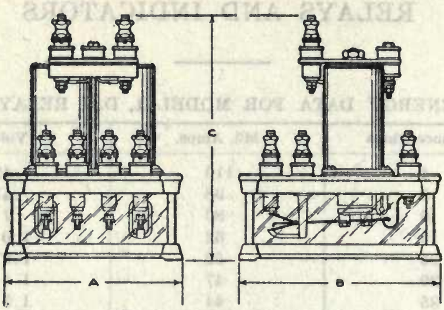


FIG. 228. MODEL 9, D.C. RELAY, SHELF TYPE

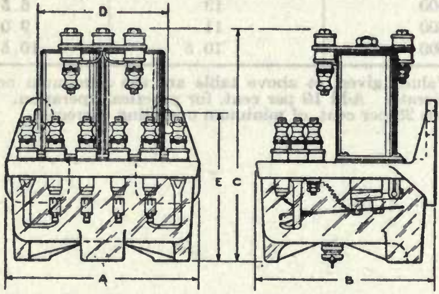


FIG. 229. MODEL 9, D.C. RELAY, WALL TYPE

DIMENSIONS OF MODEL 9 D. C. RELAYS

Name	No. of Fingers	A	B	C	D	E
Model 9 Form A4 Neutral Relay, . . .	4	$6\frac{5}{16}$	$7\frac{3}{16}$	9	..	..
Model 9 Form A6 Neutral Relay, . . .	6	$8\frac{9}{16}$	$7\frac{3}{16}$	9	..	..
Model 9 Form A8 Neutral Relay, . . .	8	$10\frac{13}{16}$	$7\frac{3}{16}$	9	..	..
Model 9 Form C4 Neutral Relay, . . .	4	$6\frac{5}{16}$	$7\frac{3}{16}$	9	..	..
Model 9 Form A4 Neutral Wall Relay, .	4	$6\frac{7}{8}$	$6\frac{7}{16}$	$8\frac{1}{2}$	$5\frac{3}{8}$	$4\frac{1}{2}$
Model 9 Form A6 Neutral Wall Relay, .	6	8	$6\frac{7}{16}$	$8\frac{1}{2}$	$5\frac{3}{8}$	$4\frac{1}{2}$
Model 9 Form A4 Polarized Relay, . . .	4	$6\frac{5}{16}$	$7\frac{3}{16}$	9	..	..
Model 9 Form A6 Polarized Relay, . . .	6	$8\frac{9}{16}$	$7\frac{3}{16}$	9	..	..
Model 9 Form A4 Polarized Wall Relay,	4	$6\frac{7}{8}$	$6\frac{7}{16}$	$8\frac{1}{2}$	$5\frac{3}{8}$	$4\frac{1}{2}$
Model 9 Form A6 Polarized Wall Relay,	6	8	$6\frac{7}{16}$	$8\frac{1}{2}$	$5\frac{3}{8}$	$4\frac{1}{2}$
Model 9 Interlocking Relay, ...		$6\frac{5}{16}$	$12\frac{11}{16}$	8	..	..

ENERGY DATA FOR MODEL 9, D. C. RELAYS

Resistance Ohms.	4 Way		6 Way		8 Way	
	Mil. Amps.	Volts	Mil. Amps.	Volts	Mil. Amps.	Volts
3.5	79	.28	95	.34	111	.39
4	75	.30	90	.36	105	.42
4.2	71	.30	85	.36	100	.42
5	71	.36	85	.43	100	.50
6	64	.38	76	.46	85	.51
7	57	.40	69	.49	81	.57
9	53	.48	64	.58	75	.68
10	51	.51	61	.61	72	.72
11	47	.52	56	.62	66	.73
12	51	.61	61	.73	72	.87
16	41	.66	49	.79	57	.92
17	38	.65	46	.79	54	.92
20	38	.76	46	.93	54	1.08
26	31	.81	37	.97	44	1.15
35	31	1.08	37	1.30	44	1.54
40	27	1.08	33	1.32	38	1.52
46	24	1.11	29	1.34	34	1.57
50	23	1.15	27	1.35	32	1.60
60	21	1.26	25	1.50	30	1.80
68	20	1.36	24	1.64	28	1.91
75	21	1.57	26	1.95	29	2.18
80	20	1.60	25	2.00	29	2.32
90	18	1.62	23	2.07	27	2.43
98	17	1.67	21	2.06	25	2.45
125	15	1.88	18	2.25	21	2.63
150	14	2.10	16	2.40	19	2.85
200	13	2.60	16	3.20	18	3.60
244	11	2.68	14	3.42	16	3.91
300	11	3.30	13	3.90	15	4.50
346	10	3.46	12	4.15	14	4.85
400	10	4.00	12	4.80	14	5.60
500	8.5	4.25	10	5.00	12	6.00
516	8.5	4.39	10	5.16	12	6.19
600	8.5	5.10	10	6.00	12	7.20
670	7.5	5.02	9	6.03	11	7.37
800	8	6.40	9.3	7.44	11	8.80
900	7.5	6.75	8.5	7.65	10	9.00
1000	7	7.00	8	8.00	9	9.00
1500	6	9.00	7	10.5	8	12.00
1600	5.5	8.80	6.5	10.40	7.5	12.00

Note.—Values given in above table are the minimum on which the relay will operate. Add 10 per cent. for practical operation. Drop away current equals 40 per cent. of minimum operating current.

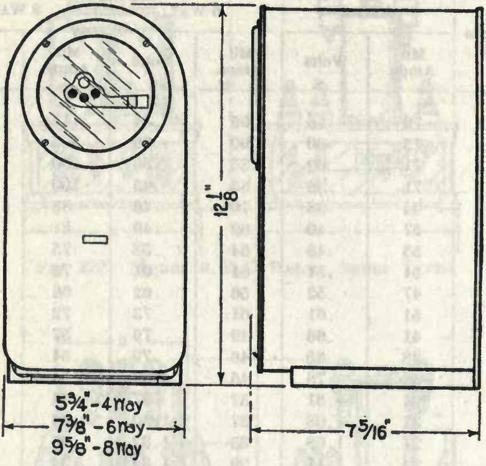


FIG. 230. MODEL 9, D. C. INDICATORS

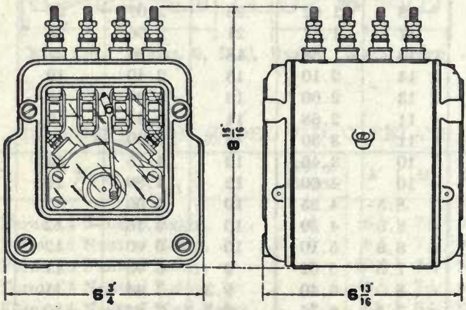


FIG. 231. THREE POSITION D. C. MOTOR RELAY

This relay requires the same amount of energy for operation as the Model 9, D. C. Relay. Drop away current equals 50 per cent. of normal operating current.

ENERGY DATA FOR MODEL 9, D. C. INDICATORS

Resis.	Tower Indicators						Switch Indicator	
	4 Way		6 Way		8 Way			
Ohms	Mil. Amps.	Volts	Mil. Amps.	Volts	Mil. Amps.	Volts	Mil. Amps.	Volts
4	101	.40	107	.43	113	.45	101	.40
4.4	94	.42	100	.44	106	.47	94	.42
6.8	75	.51	79	.54	83	.56	75	.51
9	66	.60	70	.63	74	.66	66	.60
9.2	65	.60	69	.63	73	.67	65	.60
14	55	.77	58	.82	61	.85	55	.77
20	45	.90	48	.97	51	1.02	45	.90
22	44	.96	47	1.03	50	1.10	44	.96
30	37	1.11	39	1.18	41	1.23	37	1.11
34	35	1.19	37	1.26	39	1.33	35	1.19
40	30	1.20	32	1.28	34	1.36	30	1.20
50	29	1.45	31	1.55	33	1.65	29	1.45
56	27	1.51	29	1.62	31	1.73	27	1.51
92	24	2.20	26	2.39	28	2.57	24	2.20
100	22	2.20	23	2.30	25	2.50	22	2.20
130	19	2.47	20	2.60	21	2.73	19	2.47
200	15	3.00	16	3.20	17	3.40	15	3.00
300	13	3.90	14	4.20	15	4.50	13	3.90
500	11	5.50	12	6.00	13	6.50	11	5.50
690	8.5	5.86	9	6.21	9.5	6.55	8.5	5.86
1000	7.5	7.50	8	8.00	8.5	8.50	7.5	7.50

Note.—Values given in above table are the minimum on which the indicator will operate. Add 10 per cent. for practical operation. Drop away current equals 33 per cent. of minimum operating current.

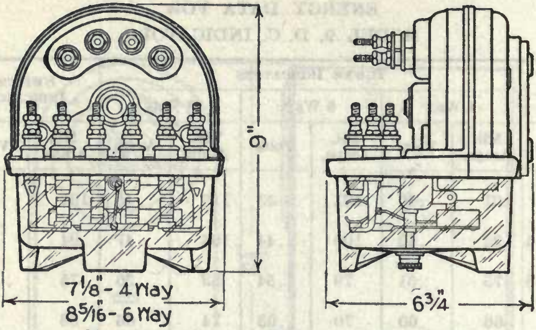


FIG. 232. RELAY—WALL OR SHELF TYPE

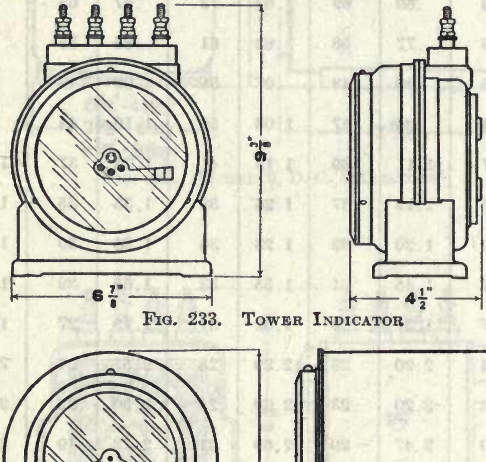


FIG. 233. TOWER INDICATOR

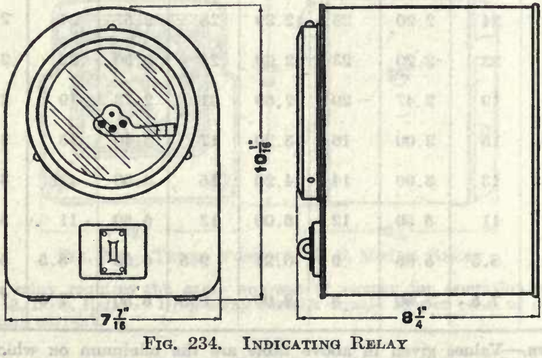


FIG. 234. INDICATING RELAY

MODEL 2 FORM B, MODEL 3 FORM B, OR MODEL Z FORM B, A. C. RELAYS AND INDICATORS

ENERGY DATA FOR A. C. LINE RELAYS AND INDICATORS

For Use on 55–110 or 220 Volts, — 25 or 60 Cycles.

Name of Device	Cycles	Maximum Energy Required at Normal Voltage (see Note)					
		2 Position		3 Position			
		Split Phase		Local		Line	
		V. A.	Watts	V. A.	Watts	V. A.	Watts
Model 2 Form A Line Relays, with 6 front, 6 back or 12 front contacts, and indicating attachment for tower use, ...	25 60	12.0 12.0	10.0 10.0	7.8 7.8	5.4 5.4	6.4 6.4	5.4 5.4
Model 2 Form B Line Relays, with 6 front, 2 back contacts, and indicating attachment for tower use, .	25 60	15.0 15.0	10.0 10.0	11.7 11.7	5.4 5.4	6.5 6.5	5.4 5.4
Model Z Form B Line Relays, with 6 front, 2 back contacts, and indicating attachment for tower use, .	25 60	5.5 10.0	2.0 3.0	... ...	... ...	... ...	... ...
Model 2 Form B Switch Indicator, without contacts, ...	25 60	15.0 15.0	10.0 10.0	... ...	... ...	... ...	... ...
Model Z Form B Switch Indicator, without contacts, ...	25 60	3.0 5.5	1.5 1.8	... ...	... ...	... ...	... ...
Model 2 Form B Tower Indicator, without contacts, ...	25 60	15.0 15.0	10.0 10.0	... ...	... ...	... ...	... ...
Model Z Form B Tower Indicator, without contacts, ...	25 60	3.0 5.5	1.5 1.8	... ...	... ...	... ...	... ...

Note.— Above energy figures will permit practical operation of these devices on a voltage 20 per cent. below normal and are based on a maximum equipment of contacts, including indicating attachment for tower use. Without indicating attachment, with a lesser number of contacts, by special construction, or by combinations of any of the foregoing, the above energy may be reduced 20 to 50 per cent. Relay must drop away on not less than 50 per cent. of the minimum operating energy.

Note.— The above table permits the following line resistance in series with line phase of relay.

Volts	Cycles	Resistance (Ohms)
55	25	75
55	60	100
110	25	150
110	60	200
220	25	250
220	60	300

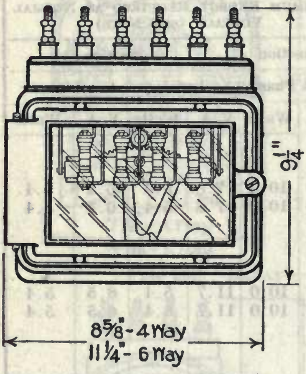


FIG. 235. MODEL 2 FORM A POLYPHASE RELAY

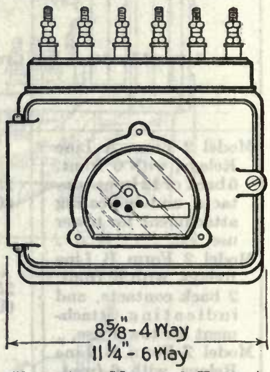


FIG. 236. MODEL 2 FORM A POLYPHASE INDICATING RELAY

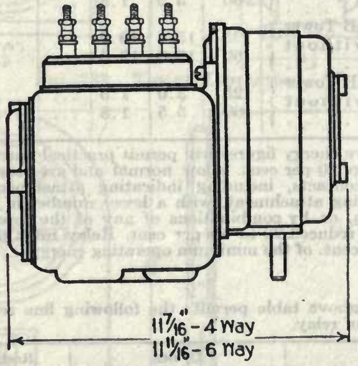


FIG. 237. SIDE VIEW OF MODEL 2 FORM A POLYPHASE RELAY OR INDICATING RELAY

OPERATION OF THE MODEL 2 FORM A REGULAR POLYPHASE RELAY, IN CONNECTION WITH DOUBLE RAIL A. C. TRACK CIRCUITS ON ELECTRIFIED DIRECT CURRENT ROADS

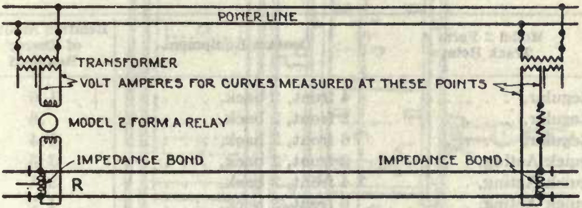


FIG. 238. END FED DOUBLE RAIL A. C. TRACK CIRCUIT

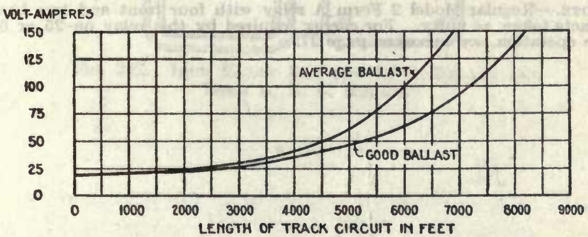


FIG. 239. CURVE SHOWING ENERGY REQUIRED FOR OPERATION ON 25 CYCLE CURRENT

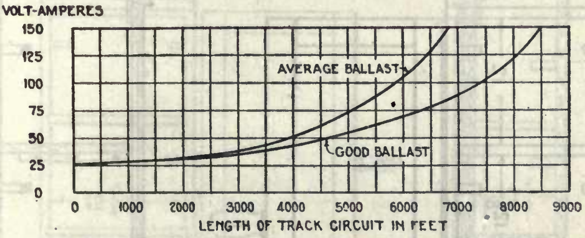


FIG. 240. CURVE SHOWING ENERGY REQUIRED FOR OPERATION ON 60 CYCLE CURRENT

NOTE.—Volt amperes shown in Figs. 239 and 240 are the total of the volt amperes fed to the track circuit and to the relay local. Relay is equipped with four front and two back contacts. Curves are based on 85 pound rail being used.

Good ballast (approximately 10 ohms per 1,000 ft.) consists of rock or gravel ballast, well drained and free from the base of the rails.

Average ballast (approximately 5 ohms per 1,000 ft.) consists of a ballast, such as a well drained gravel ballast, covering the base of the rails.

Dirt, cinder or badly drained gravel ballast, covering the base of the rails, is considered poor and necessitates the use of much more energy for the operation of track circuits than is shown in the curves.

TABLE SHOWING RELATIVE AMOUNT OF ENERGY REQUIRED FOR MODEL 2 FORM A TRACK RELAYS, REGULAR AND QUICK ACTING, WITH DIFFERENT CONTACT COMBINATIONS

Model 2 Form A Track Relays	Contact Equipment	Relative Amount of Energy Required
Regular, ...	4 front, 2 back, ...	1.0
Regular, ...	2 front, 2 back, ...	.8
Regular, ...	6 front, 2 back, ...	1.4
Quick Acting, ...	2 front, 2 back, ...	3.5
Quick Acting, ...	4 front, 2 back, ...	3.5
Quick Acting, ...	6 front, 2 back, ...	4.2

NOTE.—Regular Model 2 Form A relay with four front and two back contacts taken as unity. For energy required by this relay on 25 or 60 cycle operation, see curves on page 273.

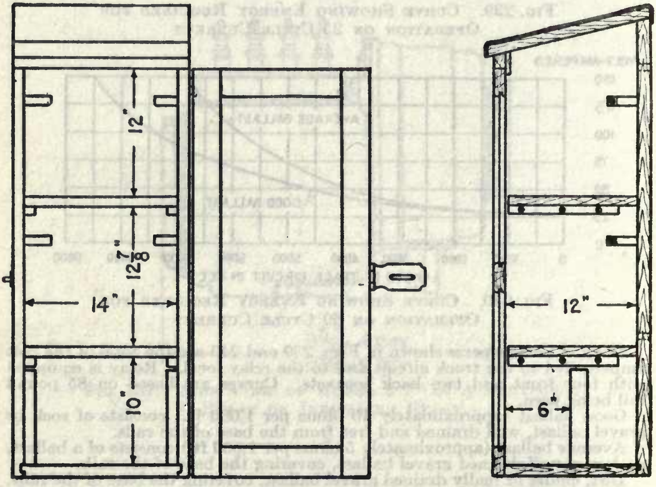


FIG. 241. WOOD RELAY BOX FOR MODEL 2 FORM A POLYPHASE RELAYS

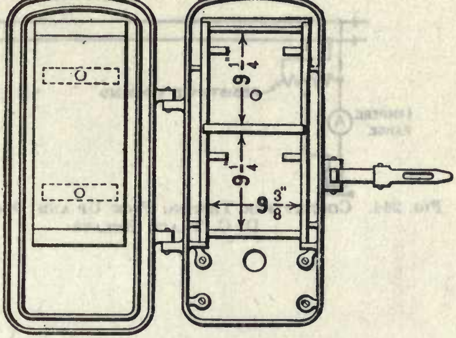


FIG. 242. IRON RELAY BOX FOR D. C. RELAYS AND FORM B, A. C. RELAYS

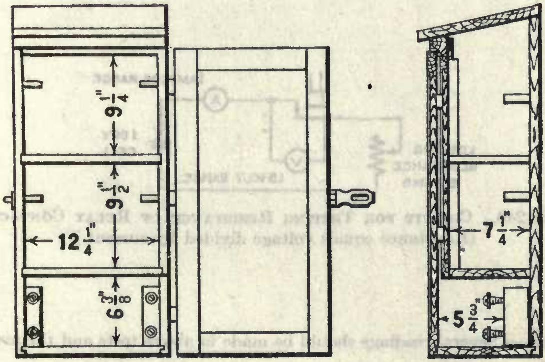


FIG. 243. WOOD RELAY BOX FOR D. C. RELAYS AND FORM B, A. C. RELAYS

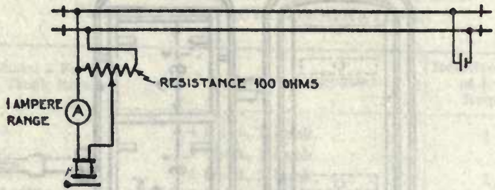


FIG. 244. CIRCUIT FOR TESTING PICK UP AND DROP AWAY OF D. C. TRACK RELAYS

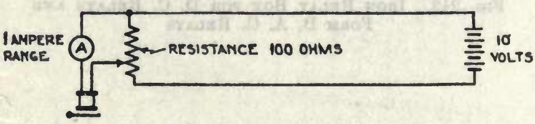


FIG. 245. CIRCUIT FOR TESTING PICK UP AND DROP AWAY OF D. C. LINE RELAYS

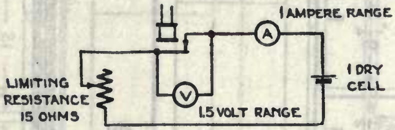


FIG. 246. CIRCUIT FOR TESTING RESISTANCE OF RELAY CONTACTS
(Resistance equals voltage divided by current.)

NOTE.— Several readings should be made in above tests and the average taken.

The resistance used in Figs. 244 and 245 consists of a resistance with a variable center connection. It should, preferably, have uniformly graduated steps. The resistance used in Fig. 246 may merely be a unit of such resistance as to protect the instrument. It is recommended, however, that a variable resistance be used if available. If voltages used in above tests are higher than those indicated, the resistances used will have to be increased accordingly.

The ammeter for all of the above tests should not have a range greatly exceeding the 1 ampere range indicated above.

INSTALLATION AND OPERATING DATA FOR TRANSFORMERS

COVERING DIMENSIONS AND RATINGS OF LINE AND TRACK TRANSFORMERS

TRANSFORMERS

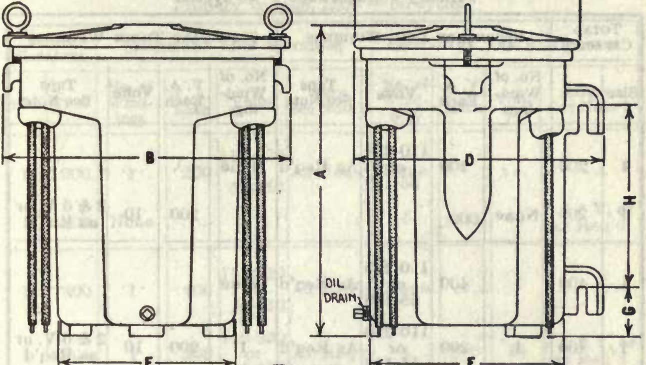


FIG. 247

DIMENSIONS OF TYPE L LINE TRANSFORMERS

Size	DIMENSIONS (APPROXIMATE)							
	A	B	C	D	E	F	G	H
	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch
1	13 13/16	12 3/4	10	11	7 7/8	8 5/8	2 5/16	8
2	15 1/4	13 5/8	11 13/16	12 13/16	8 5/8	10	3 9/16	8
3	17	15 1/4	13 1/2	14 5/8	10	11 1/2	4 9/16	8

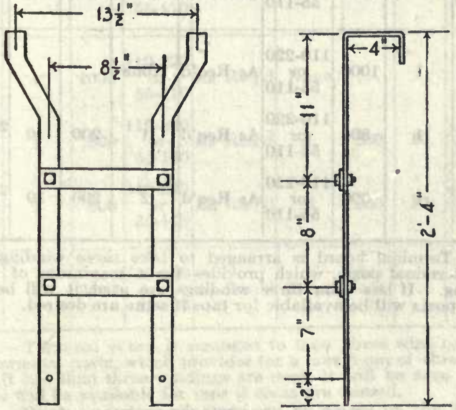


FIG. 248. HANGER IRONS

STANDARD RATINGS OF G. R. S. TYPE L TRANSFORMERS

Single Phase, Oil Immersed, Self Cooled, Pole Type

Primary voltage, 2200 — 25 cycles.

Total Capacity		Secondary Line Windings				Secondary Track Windings			
Size	V. A.	No. of Wind-ings	V. A. Each	Volts	Taps See Note	No. of Wind-ings	V. A. Each	Volts	Taps See Note
1	200	1	200	110-220 or 55-110	As Req'd	None	...	...	......
1	200	None	...	....	....	1	200	10	2 & 6 V, or as Req'd
1	400	1	400	110-220 or 55-110	As Req'd	None	...	...	......
1	400	1	200	110-220 or 55-110	As Req'd	1	200	10	2 & 6 V, or as Req'd
1	400	None	...	....	....	2	200	10	2 & 6 V, or as Req'd
2	600	1	600	110-220 or 55-110	As Req'd	None	...	...	......
2	600	1	400	110-220 or 55-110	As Req'd	1	200	10	2 & 6 V, or as Req'd
2	600	1	200	110-220 or 55-110	As Req'd	2	200	10	2 & 6 V, or as Req'd
3	1000	1	1000	110-220 or 55-110	As Req'd	None	...	...	......
3	1000	1	800	110-220 or 55-110	As Req'd	1	200	10	2 & 6 V, or as Req'd
3	1000	1	600	110-220 or 55-110	As Req'd	2	200	10	2 & 6 V, or as Req'd

Note.— Terminal board is arranged to take three windings, each to have five terminal posts, which provides for a maximum of three taps per winding. If less than three windings are used, it will be seen that additional posts will be available for taps if same are desired.

STANDARD RATINGS OF G. R. S. TYPE L TRANSFORMERS

SINGLE PHASE, OIL IMMERSED, SELF COOLED, POLE TYPE

Primary voltage, 2200 — 60 cycles.

Total Capacity		Secondary Line Windings				Secondary Track Windings			
Size	V. A.	No. of Windings	V. A. Each	Volts	Taps See Note 1	No. of Windings	V. A. Each	Volts	Taps See Note 1
1	200	1	200	110-220 or 55-110	As Req'd	None	...	...	....
1	200	None	...	....	....	1	200	10	2 & 6 V, or as Req'd
1	400	1	400	110-220 or 55-110	As Req'd	None	...	...	......
1	400	1	200	110-220 or 55-110	As Req'd	1	200	10	2 & 6 V, or as Req'd
1	400	None	...	....	....	2	200	10	2 & 6 V, or as Req'd
1	600	1	600	110-220 or 55-110	As Req'd	None	...	...	......
1	600	1	400	110-220 or 55-110	As Req'd	1	200	10	2 & 6 V, or as Req'd
1	600	1	200	110-220 or 55-110	As Req'd	2	200	10	2 & 6 V, or as Req'd
2	1000	1	1000	110-220 or 55-110	As Req'd	None	...	...	......
2	1000	1	800	110-220 or 55-110	As Req'd	1	200	10	2 & 6 V, or as Req'd
2	1000	1	600	110-220 or 55-110	As Req'd	2	200	10	2 & 6 V, or as Req'd
3	3000	1	3000	110-220 or 55-110	As Req'd	None	See Note 2	...	......

NOTE 1.— Terminal board is arranged to take three windings, each to have five terminal posts, which provides for a maximum of three taps per winding. If less than three windings are used, it will be seen that additional posts will be available for taps if same are desired.

NOTE 2.—Track secondary windings can be placed on the 3,000 V. A. size if desired.

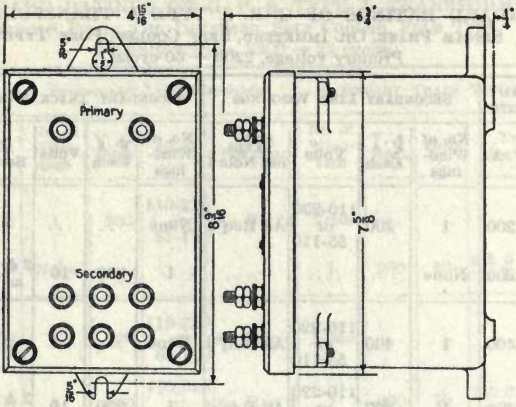


FIG. 249. TYPE K SECONDARY TRACK TRANSFORMER

STANDARD RATINGS OF G. R. S. TYPE K TRANSFORMERS

SINGLE PHASE, AIR COOLED

25 Cycles	60 Cycles
50 V. A.	50 V. A.
100 V. A.	100 V. A.
200 V. A.	200 V. A.

The above ratings are for 110 volt primary. Ten or twenty volts secondaries can be furnished, equipped with a maximum of six taps when required.

R. S. A. VOLTAGE RANGES FOR SIGNAL WORK (1913)

(1st Range) Thirty (30) and less.

(2d Range) Over thirty (30) to and including one hundred and seventy-five (175).

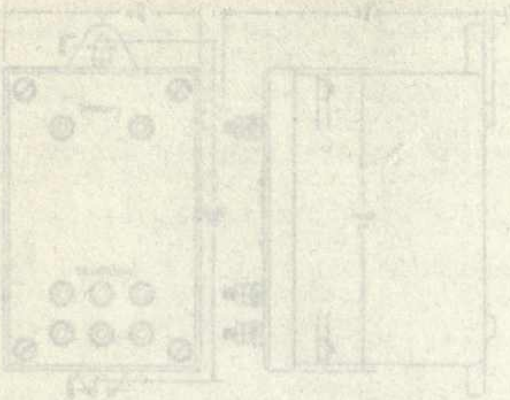
(3rd Range) Over one hundred and seventy-five (175) to and including two hundred and fifty (250).

(4th Range) Over two hundred and fifty (250) to and including six hundred and sixty (660).

(5th Range) Over six hundred and sixty (660).

INSTALLATION AND OPERATING DATA FOR PRIMARY BATTERIES

COVERING THE CAUSTIC SODA CELL, GRAVITY CELL AND DRY CELL



R. S. A. VOLTAGE RANGES FOR SIGNAL WORK

(1915)

(1st Range) Thirty (30) and less.

(2d Range) Over thirty (30) to and including one hundred and seventy-five (175).

(3rd Range) Over one hundred and seventy-five (175) to and including two hundred and fifty (250).

(4th Range) Over two hundred and fifty (250) to and including six hundred and sixty (660).

(5th Range) Over six hundred and sixty (660).

PRIMARY BATTERIES

CAUSTIC SODA PRIMARY CELL

Uses

THE caustic soda primary battery is largely used on open circuit work, such as for signal operation, where a higher current is required than can be secured from other types of primary batteries without the installation of a great number of cells. A somewhat different design of caustic soda cell is extensively used for track circuit work; although a more expensive cell than the gravity cell, it is one in which the maintenance is very slight, it being ordinarily necessary to make renewals only four or five times a year, this, of course, depending on the type of traffic passing over the section on which the battery is installed.

Description

The elements of the cell are of zinc and black oxide of copper and the electrolyte a strong solution of caustic soda and water. These are generally contained in a porcelain or heavy heat resisting glass jar, the latter being preferable due to its freedom from breakage and the ease with which inspection is made. The cut on page 286 gives the appearance of the jar adopted by the R. S. A. as their standard, the ampere hour capacity of this standard cell being 400.

The elements of the signal cell are generally cast in the form of plates which are suspended from the cover. This cell has an extremely low internal resistance (about .045 ohm) and is hence capable of producing on short circuit the heavy current of 20 amperes. The E. M. F. of the cell is low; when new, it is approximately 0.7 volt and this falls off after the cell has been in service for some time.

The elements used in the track cell are not necessarily of the same type as those used in the signal cell. One well-known cell used for track circuit work has a zinc element similar in form to the zinc in the gravity cell, the other element being poured loose over a tin disc resting on the bottom of the jar. The track cell is designed to have an internal resistance of about 0.25 ohm and a current output on short circuit of about 2 to 3 amperes. The voltage of the cell is the same as that of the signal cell.

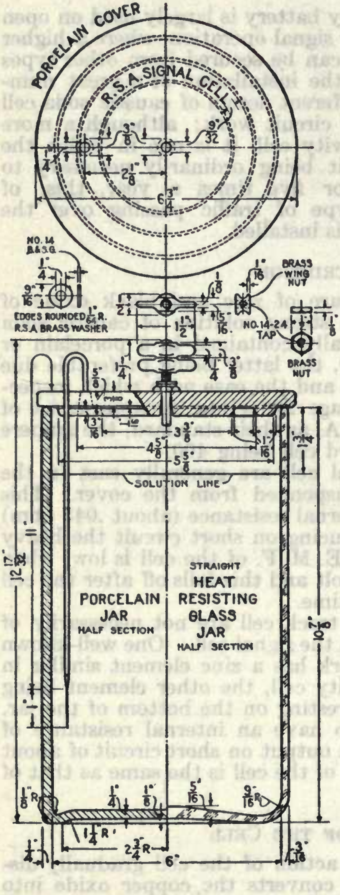
Action of the Cell

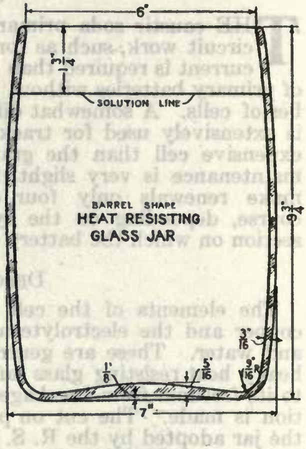
When in service, chemical action of the cell gradually dissolves the zinc element and converts the copper oxide into pure copper. In the case of the signal cell using a copper oxide plate, this change in the element will consist of the reduction of the copper oxide to copper, this reduction taking place from the surface and extending inward; the relative

R. S. A. SIGNAL CELL

Caustic Soda Primary Battery

R. S. A. plan 1053. Issue October, 1912.
(Revision of plan 1053. Issue, 1911.)





NOTES

The Assembled Element shall be so arranged that when attached to the cover and the nut on the upper side tightened to place, the element will be at the proper height in the solution.

Terminal wire shall be No. 12 B & S gauge solid soft drawn copper wire covered with an insulation suitable to withstand the action of the oil and electrolyte. Insulation on end of wire shall be trimmed either tapered or square and in this operation the wire must not be scored.

Suspension bolt shall be iron, copper plated.

Jar and Cover shall conform to the dimensions shown, with reasonable allowance for slight irregularities in manufacture.

Top of jar shall be square with vertical axis and cover shall be perfectly flat.

Manufacturer's name or trade mark shall be shown on cover.

Porcelain jars shall be glazed inside and out and covers on top and edge.

A solution line consisting of a slight ridge or depression extending around the inside of porcelain jars and the outside of glass jars shall be placed as shown.

degree of exhaustion of the cell can be ascertained by scraping off the material from the outside of the plate until the dark copper oxide is exposed. In the cell used for track circuit work, the copper oxide is converted into copper flakes which continue to lie as before on the tin disc in the bottom of the jar.

Care of the Cell

In setting up the cell, the jar should be first thoroughly cleaned and then filled with pure water (preferably clear rain water) to such a height that when the elements are added the level of the electrolyte will have been raised to within about one and one-half inches of the top of the jar. The soda should be added slowly and the solution stirred continuously with a stick until the soda is entirely dissolved. Chemical changes raise the temperature of the solution to the boiling point, making it necessary to place ordinary glass, or porcelain jars, on a dry wood surface when mixing the solution, to prevent breakage of the jars. The elements should not be placed in the cells until the temperature of the solution has dropped to about 90 degrees Fahr. A thin film of oil should then be poured over the top of the electrolyte to prevent evaporation and "creeping of the salts."

When mixing the solution, care should be taken not to get the caustic soda dust or solution on one's person, as it is very corrosive; the best means for counteracting the action of caustic soda is water or oil.

When in service practically no other attention is required by the cell other than an occasional inspection of the elements to determine the degree of exhaustion of the cell.

The caustic soda solution does not freeze, but when subjected to severe cold the current discharge of the battery is materially reduced, which makes it advisable to furnish protection against extreme temperature conditions where current for operating signal motors is required, or if an equivalent current is wanted for any other purpose.

EXTRACT FROM R. S. A. SPECIFICATIONS FOR CAUSTIC SODA PRIMARY CELL (1911)

1. General

This battery is to be used in the operation of signals, crossing alarms, etc.

2. Material

(*a*) Railway Signal Association drawing 1053, issue 1911, shows the general design and dimensions of the battery jar, cover, connections, wire, and that part of the bolt, together with nuts and washers, shown above the cover for supporting the elements. The active part of the cell consists of the zinc, copper oxide, and caustic soda in the granular form, which, mixed with water, forms the solution in which the elements are placed, and a suitable mineral oil, which is used on top of the caustic soda solution to prevent evaporation and the salts from creeping over the top of the jar.

(*b*) The assembled element shall consist of the zinc and copper oxide, suitably combined, together with the suspension bolt and terminal wire of sufficient length to extend twelve (12) inches above top of cover.

3. Requirements

Each complete cell or renewal shall have a capacity of at least four hundred (400) ampere hours, as provided for under test in Section 4.

4. Test

(*a*) In order to determine the ampere hour capacity of the cell or renewal, one will be selected at random from each lot of one hundred (100), or fraction thereof, and placed on a continuous discharge of one (1) ampere. If the discharge continues four hundred (400) hours without the potential at the terminals of the cell dropping below five-tenths (0.5) of one (1) volt per cell, the cell or renewal will be considered acceptable as far as capacity is concerned.

(*b*) One will be selected at random from each lot of one hundred (100), or fraction thereof, and subjected to a discharge of three (3) amperes continuously. If, during the first forty (40) hours, the voltage does not drop below fifty-three hundredths (0.53) of one (1) volt and during the next forty (40) hours the voltage does not drop below five-tenths (0.5) of one (1) volt, the cell or renewal will be considered acceptable so far as drop in voltage test is concerned.

(*c*) Tests enumerated in paragraphs (*a*) and (*b*) will be made at a temperature of seventy (70) degrees Fahr.

THE GRAVITY CELL

Uses

The primary cell in most general use on low voltage closed circuit work is the gravity cell; it is extensively used in connection with track circuits, being adapted to this type of work by its constant voltage characteristics and its freedom from polarization when on closed circuit. Although frequently used on open circuit work, it is not recommended that the cell be used that way, due to the very low efficiency obtained when operating under those conditions.

Description

The elements of this cell are of zinc and copper, and the electrolyte a solution formed by dissolving copper sulphate or "Blue-stone" in pure water. The electrolyte and elements are contained in a glass jar about eight inches in height and six inches in diameter.

In the type of cell generally employed for signal purposes, the zinc element consists of about four pounds of metallic zinc, cast in the shape of a ring, which is suspended from the upper edge of the glass jar by means of soft wire hangers cast into the element. The copper element, made of thin sheet copper, rests on the bottom of the jar and is covered with copper sulphate crystals.

The gravity cell has an approximately constant E. M. F. of 1 volt on open circuit and does not polarize through being continually short circuited. The internal resistance varies considerably with the condition of the cell, running from about an ohm when the cell is in good condition to as high as 2 or 3 ohms. When in the best condition the cell has a current capacity on short circuit of about 1 ampere.

Action of the Cell

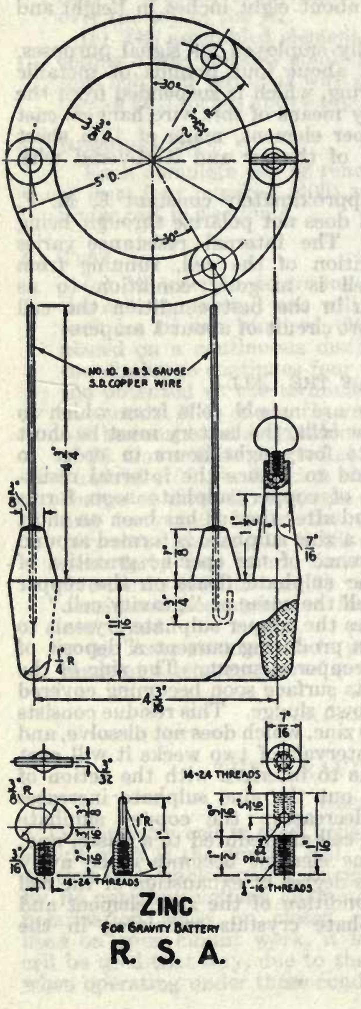
When first set up, if there are no old cells from which to get zinc sulphate to use in new cells, the battery must be short circuited from twenty-four to forty-eight hours in order to start the action of the cell and to reduce the internal resistance. A saturated solution of copper sulphate soon forms around the copper element, and after the cell has been on short circuit for a number of hours, a zinc sulphate is formed around the zinc. Due to the difference of the specific gravities of these two sulphates, the zinc sulphate floats on the copper sulphate, this giving to the cell the name of "gravity cell."

The action of the cell causes the copper sulphate crystals to dissolve, and when the cell is producing current a deposit of pure copper is made on the copper element. The zinc of the other element is consumed, its surface soon becoming covered with a deposit of grey and brown sludge. This residue consists of part of the impurities of the zinc, which does not dissolve, and if not scraped off at about intervals of two weeks it will coat the zinc to such an extent as to interfere with the action of the cell. As the cell wears out the zinc sulphate increases and the copper sulphate decreases; the copper sulphate crystals in the bottom of the cell are reduced to a paste, and, as mentioned before, the zinc element becomes eaten away by the chemical action. The degree of exhaustion of the cell can be determined by the condition of the zinc element and the amount of copper sulphate crystals remaining in the bottom of the jar.

R. S. A. ZINC

Gravity Primary Battery

R. S. A. plan 1087. Issue October, 1911.



SPECIFICATION

1. Zincs shall be made from virgin spelter cast at a low temperature and shall be thoroughly amalgamated with mercury. They shall be uniform in size and weight, free from flaws and mechanical defects and shall have a smooth outer surface. A fracture of the zinc must show the grain firm and close.

2. The size and shape of zincs shall conform closely to this drawing.

The brass binding post must be firmly connected both mechanically and electrically to the zinc. The thumb screw must be perfectly threaded and must fit closely.

The manufacturer's name must be cast on the upper flat surface of the zinc in as large letters as the surface will permit and must be raised not less than three-thirty-seconds ($\frac{3}{32}$) inch above the surface. In addition, the manufacturer's name or trade-mark must be stamped on some other part in such a position as not to be effaced by the action of the electrolyte or by the process of cleaning.

3. Weight. The zincs shall weigh four (4) pounds each.

4. The chemical composition of the finished zincs shall be as follows:

Mercury	not less than	2 00%
Iron	not more than	10%
Lead	not more than	50%
Other impurities	not more than	40%
Zinc	not less than	97 00%

5. When a shipment of zincs is received, an examination will be made to see that the physical requirements are fulfilled, and if found satisfactory, one zinc from each fifty (50) or fraction thereof will be taken for chemical analysis. The results of this analysis shall determine whether the shipment will be accepted.

In the event of controversy with the manufacturer over the chemical composition, one zinc from each 50 or fraction thereof shall be submitted to a disinterested chemist, acceptable to both manufacturer and purchaser, for analysis. If in this analysis the chemical composition of the zincs analyzed is found to be in accordance with this specification, the zincs furnished will be accepted and the cost of the analysis shall be paid by the purchaser. If the chemical composition is not found to be in accordance with this specification, all expenses in connection with the analysis including the loss on the zincs analyzed shall be borne by the manufacturer.

The manufacturer shall be advised of all material rejected as a result of chemical analysis or physical tests, and if at the expiration of two weeks no instructions are received for the return of same, the rejected material shall be returned at the risk of the manufacturer, he paying the freight in both directions in either case.

The payment for zincs shall be based upon the net weight received.

6. Zincs must be carefully and securely packed in shavings or sawdust in a stout barrel or box, in lots not to exceed fifty (50) each. The name of the manufacturer and the name of the consignee, together with the destination; number of zincs contained in the package and the purchase order number must be plainly marked on the outside of each package.

All zincs broken in transit on account of not being properly packed will be returned to the manufacturer, who must promptly replace same free of cost to the purchaser.

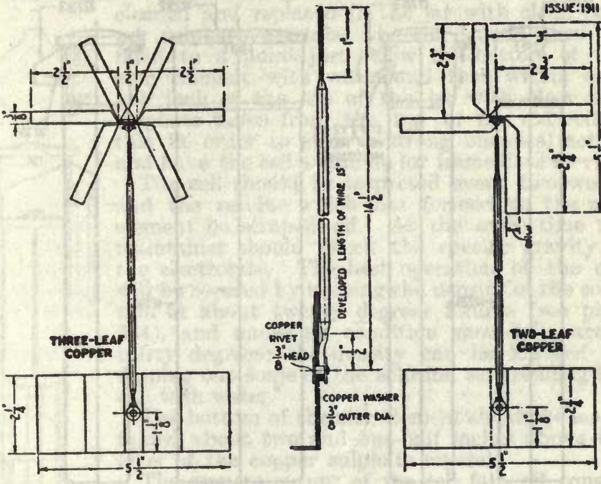
7. Thumb screws for binding posts shall be furnished only when specified.

When furnished, each box or barrel must contain at least as many thumb screws as there are zincs, the thumb screws being wrapped separately and tied to one of the zincs just under the cover.

R. S. A. COPPERS

Gravity Primary Battery

R. S. A. plan 1088. Issue October, 1911.



SPECIFICATION

1. Material. (*a*) Coppers shall be two-leaf or three-leaf as specified and shall conform to the above drawing. Leaves shall be No. 30 B & S gauge, hard rolled bright copper not less than ninety-eight (98) per cent. pure.

(*b*) Lead wire shall be No. 14 B & S gauge, solid soft drawn copper, insulated throughout the entire length, except one (1) inch at each end. The insulation shall consist of a three-sixty-fourths (3/64) inch wall of rubber, shall adhere tightly to the wire and shall be of a character suitable to withstand the action of the battery solution. Insulation on ends of wire to be trimmed either tapered or square, and in this operation the wire must not be scored.

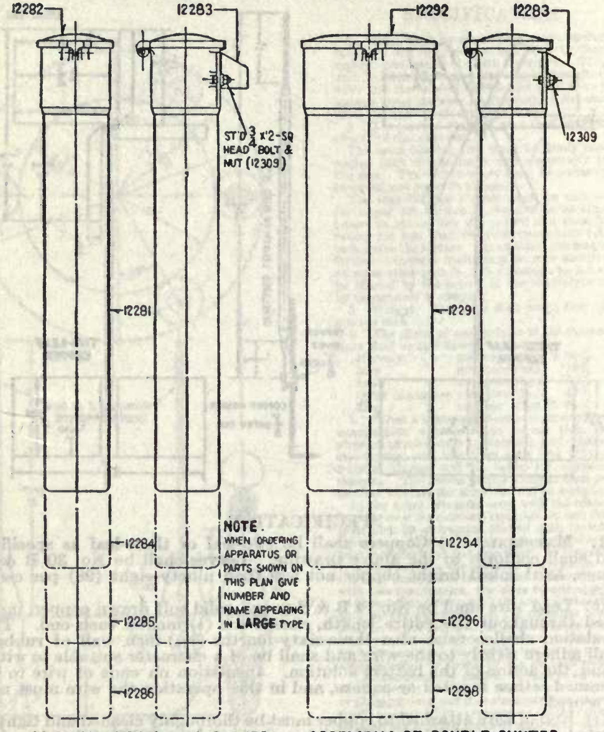
(*c*) End of wire attached to copper must be thoroughly cleaned and tightly riveted as shown with a rivet having a three-eighths (3/8) inch head and a washer three-eighths (3/8) inch in outer diameter. Both rivets and washer shall be copper not less than ninety-eight (98) per cent. pure.

2. Packing and Marking. Copper shall be carefully and securely packed in lots of one-hundred (100) each, or fifty (50) if so specified, and the purchase order number, contents of package, name of manufacturer and name and address of consignee shall be plainly marked on the outside of each package.

3. Inspection and Acceptance. One copper taken at random from each fifty (50) or fraction thereof shall be examined and tested. The results of this examination shall determine whether the lots so represented will be accepted. If the samples are found to meet this specification, the material will be accepted. If any of the samples fail to meet this specification, the lots represented will be rejected and returned at the risk of the manufacturer, he paying the freight in both directions.

R. S. A. BATTERY CHUTES

R. S. A. plan 1230. Issue December, 1912.



ASSEMBLY OF SINGLE CHUTES	ASSEMBLY OF DOUBLE CHUTES
12301 = 6 FT. CHUTE	12303 = 6 FT. CHUTE
12302 = 6 FT. " [WITH 12278]	12304 = 6 FT. " [WITH 122710 - 12293]
12305 = 7 FT. "	12307 = 7 FT. "
12306 = 7 FT. " [WITH 12278]	12308 = 7 FT. " [WITH 122710 - 12295]
12309 = 8 FT. "	123011 = 8 FT. "
123010 = 8 FT. " [WITH 12278]	123012 = 8 FT. " [WITH 122710 - 12297]
123013 = 9 FT. "	123015 = 9 FT. "
123014 = 9 FT. " [WITH 12278]	123016 = 9 FT. " [WITH 122710 - 12299]

Care of the Cell

In making renewals, the jars should be well washed, being scoured until they are transparent. The elements should be cleaned and replaced in the jar with clean copper sulphate crystals; the cell should then be filled to a point just below the bottom of the zinc element with water and then within one-half inch of the top of the jar with clear zinc sulphate taken from the top of the old cell — this in order to start a strong chemical action and have the cell available for immediate service.

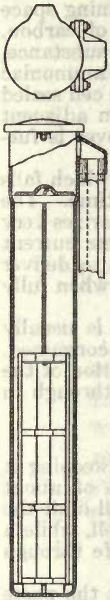


Fig. 250. Section of Single Battery Chute with Three-Cell Elevator

The cell should be inspected every two weeks and the residue which has formed on the zinc element be scraped off. At the same time the maintainer should check the specific gravity of the electrolyte. The best operation of the cell will be secured by keeping the density of the solution at about twenty degrees Baume (see page 384), and under no condition should it exceed thirty degrees; the density can be lowered by dipping out some of the solution and refilling the cell with water.

The bottom of the zinc element should be maintained about two and one-half inches above the level of the copper sulphate crystals.

The ampere output of the cell falls off considerably with a decrease in temperature. Under no conditions should the cell be exposed to a temperature below thirty-two degrees Fahr., as the solution congeals at slightly below that point and freezes with a further reduction in temperature, this interrupting the action of the cell and in a great many cases breaking the jar. When installed outside of the interlocking station the cells are housed in battery chutes or wells set in the ground to place them beyond the reach of frost, the proper depth of the housing depending on climatic conditions.

THE DRY CELL

Uses

The dry cell is most commonly used in connection with circuits which are only closed momentarily, or for a few seconds at infrequent intervals. It is employed for such purposes as operating annunciators, buzzers, etc., and sometimes in the ignition circuit of gasoline engines.

Description

The cell is contained in a zinc shell which forms one element; the other element consists of a stick of carbon set in the center of the cell. The zinc shell is usually lined with several thicknesses of blotting paper and the remaining space around the carbon element filled with a mixture of carbon, manganese dioxide, sawdust, or other absorbent substance. This mixture is then saturated with a solution of sal ammoniac (muriate of ammonia) and water, and the top of the cell sealed with wax or pitch. To insulate the zinc shell from adjacent cells, metal pipes, etc., a cylindrical pasteboard cover is furnished covering the sides and bottom of the cell.

The cell has an approximate E. M. F. of 1.5 volts which falls off after the cell has been in service for some time. The internal resistance is about .075 ohm. The cell polarizes very quickly when on short circuit, giving less and less current as it becomes more polarized, until it finally refuses to deliver current at all; the cell takes some time to recover when fully polarized.

Exhaustion of the cell, except when polarized, is usually due to the sal ammoniac having been entirely consumed. The zinc container is gradually consumed by the action of the cell, this resulting in "puncturing," or the eating through in spots, of the zinc.

Care of the Cell

The cell practically requires no care other than keeping it in a dry place which has an even temperature of about seventy degrees Fahr. Temperatures below this will limit the amount of current which can be drawn from the cell, while a greater temperature materially reduces the cell's life through drying up the sal ammoniac.

The cell is in reality a wet cell, sealed to prevent the paste from drying out. If the cell does actually become dry it will not produce any current, but if the elements have not been worn out this can be overcome by boring a hole in the top of the cell and soaking it in water for two or three days.

Care should be taken to avoid handling the cells roughly, as the contents of the cell are apt to become broken away from the carbon electrode, this resulting in an increase of the internal resistance of the cell and a consequent reduction in the current output.

EDITOR'S NOTE

Articles on primary cells, pages 285, 288 *and* 293, *based on data furnished by National Carbon Co.*

WIRE, TRUNKING AND CONDUIT

COVERING INSTALLATION PRACTICE, TABLES OF PHYSICAL PROPERTIES OF WIRE, REQUIRED SIZES OF CONTROL AND COMMON WIRES, TRUNKING CONSTRUCTION, AND THE CARRYING CAPACITIES OF TRUNKING AND CONDUIT

WIRE AND WIRING

EXTRACTS FROM R. S. A SPECIFICATIONS FOR ELECTRIC INTERLOCKING (1910)

521. Size

(*a*) Wires shall be of sufficient size to permit operation of switch and signal mechanism in accordance with previous specifications.

(*b*) Rubber-covered wire smaller than number fourteen (14) B. &. S. gauge shall not be used.

(*c*) Hard-drawn copper line wire shall not be smaller than number ten (10) B. & S. gauge.

(*d*) No common return wire shall be less than number twelve (12) B. & S. gauge.

(*e*) In submarine cable work spare wires up to twenty-five (25) per cent. of the number in use shall be provided as specified. When spare wires are required in other than cable work the number and size shall be specified.

(*f*) Numbers and sizes of track circuit connections shall be as follows:

	No. of conductors	B. & S. gauge
1. Track batteries to rail	one (1)	nine (9) or...(.)
2. Relays to rail	one (1)	nine (9) or...(.)
3. Fouling shunt connections	two (2)	nine (9) or...(.)
4. Switch circuit controller connections	two (2)	nine (9) or...(.)
5. Wire from trunking to track batteries in chutes, stranded		twelve (12) or...(.)

(*g*) Wires connected to track shall be rubber-covered soft-drawn copper.

525. Wiring

(*a*) Wires in trunking, chases or conduits shall be laid loosely without stretching or crowding.

(*b*) Not more than two (2) wires shall be connected to one (1) binding post or terminal screw.

(*c*) Unless otherwise specified, all wires shall be run as separate conductors.

526. Common Return

(*a*) Reductions in size of common wire and connections to pole lines shall be made in junction boxes.

(*b*) Connections between branches and main common wires shall be made in junction boxes.

Note.—Wire sizes given in (*f*) taken from R. S. A. Automatic Block Signal Specifications (521-*f* dated 1913).

(*c*) Unless otherwise specified, common return wires shall be continuous without joints or breaks from interlocking machine to the limits of the interlocking plant.

527. Joints in Wire

(*a*) Wires shall, as far as practicable, be continuous without joints or breaks between interlocking machine and the unit operated; joints when made shall be in junction boxes, and only made on permission from the Engineer.

(*b*) In making joints, braid shall be pulled back one (1) inch from end of rubber on each side of splice, and rubber cut with knife held at an angle of approximately thirty (30) degrees with axis of wire, as one would sharpen a pencil.

(*c*) After removing rubber, wire shall be thoroughly cleaned, care being taken to prevent injury from small cuts or nicks.

(*d*) Wire, after being cleaned, shall be twisted together in the form of a regular line wire splice, turns being spaced approximately one-sixty-fourth ($1/64$) inch.

(*e*) Joints shall then be soldered by pouring on them, or dipping them into, melted solder, a non-corrosive rosin flux being used. After soldering, joints shall be painted with .... insulating paint or with........... compound.

(*f*) Joints shall then be covered with two (2) layers of .... insulating tape between ends of braid, which tape shall be heated sufficiently to form a tight covering, but not enough to injure the quality of the material. Coating of..........insulating paint or..........compound shall be put on over insulating tape and two (2) layers of .... adhesive or friction tape shall be applied, after which the outside of the joint is to be painted with .... insulating paint.

528. Fuses

Material.

(*a*) Fuses shall be of the enclosed type.

Field work.

(*b*) The necessary fuses to properly protect all apparatus and circuits shall be installed.

(*c*) Fuses outside of buildings shall be enclosed in weatherproof boxes.

(*d*) In the lighting circuits, a fuse shall be provided in the circuit to each signal lamp; in the circuit to each set of lamps on a mast; in each branch circuit leaving the mains, and in each set of mains leaving the switchboard.

(*e*) Double pole fuse cut-out shall be provided for each circuit on the power board.

(*f*) An additional double pole fuse cut-out shall be placed in storage battery leads as near as possible to the battery terminals.

530. TAGS.

Material.

(*a*) Tags shall be made of vulcanized sheet fibre, not less than one-sixteenth (1/16) inch thick, firmly attached to the wire by the best quality yacht marline one-sixteenth (1/16) inch in diameter.

(*b*) The tag shall have a stamped imprint to show the function of the wire.

Field work.

(*c*) Wires shall be tagged at all junction boxes, switches, signals, relay boxes, arrester boxes, and at all line wire connections, unless otherwise specified.

FLUXES FOR SOLDERING AND WELDING

Iron, ...	Borax.
Tinned Iron, ...	Resin.
Copper and brass, . .	Sal ammoniac.
Zinc, ...	Chloride of zinc.
Lead, ...	Tallow or resin.
Lead and tin pipes, . .	Resin and sweet oil.
Steel, ...	Pulverize — 1 part sal ammoniac, 10 parts borax, and fuse until clear. When solidified, pulverize to powder.

INSTRUCTIONS FOR SPLICING, SOLDERING, AND TAPING JOINTS IN RUBBER-COVERED WIRE

STRIPPING THE INSULATION

When stripping the insulation, the knife blade should be held at such an angle as one would use in sharpening a pencil; do not hold the blade at right angles to the wire, as the wire is apt to be nicked if this is done.

SPLICING STRANDED WIRE TO STRANDED WIRE

Remove the insulation carefully from the end of each wire for three to four inches, according to the size of the wire. Remove the braid about one inch further back from the bare portion of the wire, being careful not to cut the rubber. If the strands become untwisted, twist together and clean thoroughly of rubber, leaving the wire bright.

Starting as shown in Fig. 251, twist the wires together in the regular manner of making a line wire joint; cut off surplus wire, as shown in Fig. 252, and solder and tape as described under "Soldering" and "Taping." See Figs. 253 and 254 for appearance of soldered and finished joints.

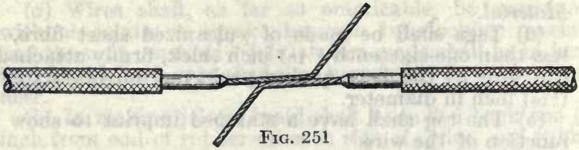


Fig. 251

Fig. 252

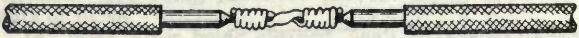


Fig. 253

Fig. 254

Splicing Stranded Wire to Stranded Wire

Splicing Stranded Wire to Solid Wire

Remove the insulation from the solid wire for about one and one-half inches and from the stranded wire for three to four inches, according to the size of the wire. Remove the braid for about one inch back from the bare portion of the wire. being careful not to cut the rubber.

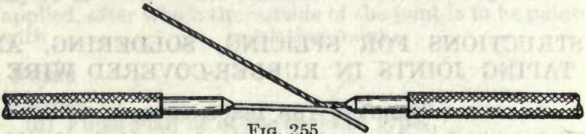


Fig. 255

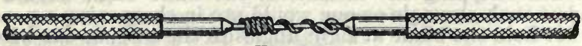


Fig. 256

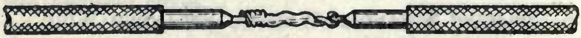


Fig. 257

Fig. 258

Splicing Stranded Wire to Solid Wire

Clean both stranded and solid wires, leaving them bright. If the strands of the stranded wire become untwisted, twist them together and starting as shown in Fig. 255, twist the stranded wire around the solid wire, leaving about the thickness of the stranded wire between the turns for about two turns, and then wind close; cut off the solid wire, leaving enough to turn an eye around the stranded wire as shown in Fig. 256. Solder and tape as described under "Soldering" and "Taping."

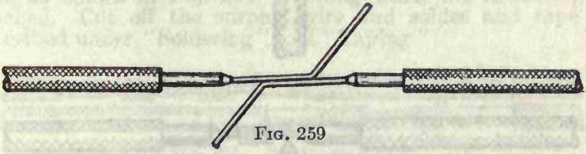


Fig. 259

Fig. 260

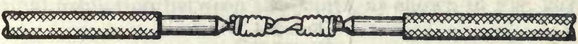


Fig. 261

Fig. 262

Splicing Solid Wire to Solid Wire

Splicing Solid Wire to Solid Wire

The insulation should be removed from four to six inches from the end of each wire. Remove the braid for about one inch from the ends of the insulation. The bare wire should be thoroughly cleaned of all rubber. Lay the two wires together so that the distance between the insulations will be about one and one-half or one and three-fourths inches, as shown in Fig. 259. Hold the middle of the joint with the pliers and twist the end of one wire around the other, leaving about one sixty-fourth inch between turns for solder to run in, as shown in Fig. 260. This winding should stop when the insulation is reached and the surplus wire then be cut off. The other end should be wound in this same manner and the middle part twisted for three or four turns. Solder and tape the joint as described under "Soldering" and "Taping."

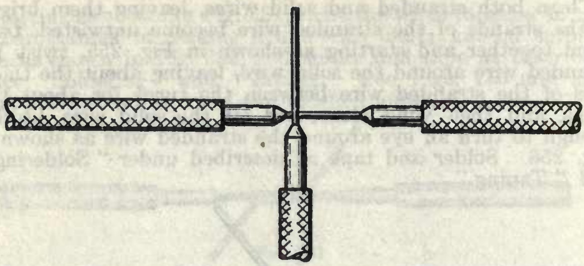


FIG. 263

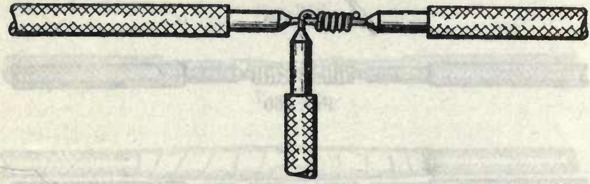


FIG. 264

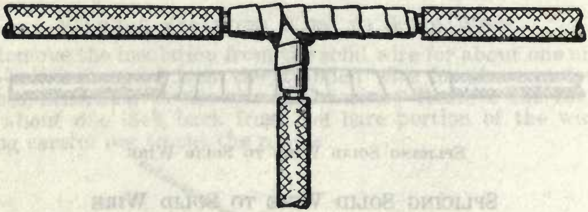


FIG. 265

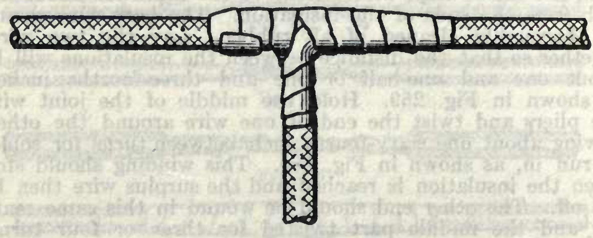


FIG. 266

MAKING T JOINTS IN SOLID WIRE

Making T Joints in Stranded or Solid Wires

Remove the insulation from the continuous wire where the joint is to be made for about one and one-fourth inches and the braid for about one inch beyond the ends of the insulation. Remove the insulation from the end of the tap wire in the same manner as described for joints in solid wire. Lay the end of the tap wire across the bare part of the continuous wire as shown in Fig. 263 and wrap around the continuous wire as shown in Fig. 264, stopping when the insulation is reached. Cut off the surplus wire and solder and tape as described under "Soldering" and "Taping."

Fig. 267. Parallel Joints

Parallel Joints

When two or more joints come side by side, as sometimes happens in parallel wires, one joint should be lapped beyond the other so as to leave at least three-fourths inch of the original insulation between the joints, as shown in Fig. 267.

Soldering

In soldering it is recommended that an approved soldering compound in stick form, such as Allen's Soldering Compound, be used. Joints should be soldered by pouring melted solder over the joint or, if impractical to do this, the work should be done with a well-tinned soldering copper having sufficient heat to thoroughly heat the entire joint. *Never use an open flame for soldering joints.*

Fig. 268

Fig. 269

Method of Taping

Taping

All joints whether for inside or outside work must be taped with Okonite tape (or its equivalent) in the following manner: The tape should first be stretched to insure its laying tight to the wire. Start the tape close up to the rubber insulation (see Fig. 268) and wind with a half lap over the joint and rubber insulation to, but not over, the braid at the end; thence back over joint and rubber insulation to, but not over, the braid on the other end, and then back to where taping was started (see Fig. 269). Warm the joint sufficiently to soften the tape slightly, squeezing the tape down with the hand to make it adhere closely to the rubber insulation and to itself.

Black friction tape of good quality should be applied over the rubber tape, using three-eighths inch tape for No. 16 wire or smaller, five-eighths inch tape for No. 14 to No. 10 wire inclusive, and three-fourths inch tape for wires larger than No. 10. Start the tape near the middle of the joint and using a half lap, wind about one-half inch beyond the braid at one end; then back to one-half inch beyond the braid at the other end, thence back and finish near the middle of the joint. In order to make a neat, strong joint, it is necessary to draw the tape tight during the whole operation.

See Figs. 254, 258, 262, and 266 for appearance of finished joints. Care should be taken to keep the hands free from oils or grease, as these will injure both the rubber tape and the adhesive qualities of the friction tape.

COMPARISON OF BROWN & SHARPE AND BIRMINGHAM WIRE GAUGES

Brown & Sharpe Gauge				Birmingham Wire Gauge			
Gauge Number	Diam. in Inches	Area: Circular Mils	Area: Square Inches	Gauge Number	Diam. in Inches	Area: Circular Mils.	Area: Square Inches
0000	.4600	211600	.166190	0000	.4540	206100	.161883
000	.4096	167800	.131790	000	.4250	180600	.141863
00	.3648	133100	.104518	00	.3800	144400	.113411
0	.3249	105500	.082887	0	.3400	115600	.090792
1	.2893	83690	.065732	1	.3000	90000	.070686
2	.2576	66370	.052128	2	.2840	80660	.063347
3	.2294	52630	.041339	3	.2590	67080	.052685
4	.2043	41740	.032784	4	.2380	56640	.044488
5	.1819	33100	.025999	5	.2200	48400	.038013
6	.1620	26250	.020618	6	.2030	41210	.032365
7	.1443	20820	.016351	7	.1800	32400	.025447
8	.1285	16510	.012967	8	.1650	27230	.021382
9	.1144	13090	.010283	9	.1480	21900	.017203
10	.1019	10380	.008155	10	.1340	17960	.014103
11	.0907	8234	.006467	11	.1200	14400	.011310
12	.0808	6530	.005129	12	.1090	11880	.009331
13	.0720	5178	.004067	13	.0950	9025	.007088
14	.0641	4107	.003225	14	.0830	6889	.005411
15	.0571	3257	.002558	15	.0720	5184	.004072
16	.0508	2583	.002029	16	.0650	4225	.003318

NOTE.—1 Mil. = .001 inch. 1 Circular Mil. = Area of 1 Mil. diameter.

SOFT-DRAWN COPPER WIRE

Number B. & S. Gauge	Diameter Bare Wire in Inches	Resistance in Ohms at 68° F.		Weight in Pounds			
				Bare Wire		R. S. A. Insulation	
		Per 1000 Ft.	Per Mile	Per 1000 ft.	Per Mile	Per 1000 ft.	Per Mile
0	.325	.10	.52	320	1687	525	2772
1	.289	.12	.65	253	1337	423	2233
2	.258	.16	.82	201	1062	358	1890
4	.204	.25	1.31	126	667	224	1183
6	.162	.39	2.08	79	419	158	834
8	.128	.63	3.31	50	264	116	613
9	.114	.79	4.18	40	209	85	449
10	.102	1.00	5.27	31	166	80	422
12	.081	1.59	8.37	20	104	61	322
14	.064	2.52	13.31	12	66	50	264
16	.051	4.01	21.17	8	41	32	169

GALVANIZED IRON AND STEEL WIRE

Number B. W. G.	Diameter in Inches	Breaking Weights Pounds		Resistance per Mile in Ohms. at 68° F.			Weight in Pounds					
							Bare Wire		Double Braid Weather-proof		Triple Braid Weather-proof	
		Iron	Steel	E.B.B	B.B.	Steel	Per 1000 ft.	Per Mile	Per 1000 ft.	Per Mile	Per 1000 ft.	Per Mile
0	.340	4821	9079	2.93	3.42	4.05	304	1607	...	...	...	...
1	.300	3753	7068	3.76	4.4	5.2	237	1251	...	...	...	...
2	.284	3363	6335	4.19	4.91	5.8	212	1121	...	...	...	...
4	.238	2361	4449	5.97	6.99	8.26	149	787	163	860	178	940
6	.203	1719	3237	8.21	9.6	11.35	109	573	126	665	140	740
8	.165	1134	2138	12.42	14.53	17.18	72	378	89	470	100	525
9	.148	915	1720	15.44	18.06	21.35	58	305	76	400	85	450
10	.134	750	1410	18.83	22.04	26.04	47	250	66	350	76	400
12	.109	495	933	28.46	33.3	39.36	31	165	43	225	49	260
14	.083	288	541	49.08	57.44	67.88	18	96	28	145	33	175
16	.065	177	332	80.03	93.66	110.7	11	59	...	...	...	...

HARD-DRAWN COPPER WIRE

Number B. & S. Gauge	Diameter Bare Wire in In.	Breaking Weight in Pounds	Resistance in Ohms at 68° F.		Weight in Pounds					
					Bare Wire		Double Braid Weatherproof		Triple Braid Weath'rproof	
			Per 1000 Ft.	Per Mile	Per 1000 Ft.	Per Mile	Per 1000 Ft.	Per Mile	Per 1000 Ft.	Per Mile
0	.325	4973	.10	.53	320	1687	377	1989	407	2150
1	.289	3943	.13	.67	253	1337	294	1553	316	1670
2	.258	3127	.16	.85	201	1062	239	1264	260	1370
4	.204	1967	.26	1.35	126	667	151	795	164	865
6	.162	1237	.41	2.14	79	419	100	529	112	590
8	.128	778	.64	3.39	50	264	66	349	75	395
9	.114	617	.81	4.29	40	209	54	283	62	325
10	.102	489	1.02	5.41	31	166	46	241	53	280
12	.081	307	1.62	8.60	20	104	30	158	35	185
14	.064	193	2.20	11.59	12	66	20	107	25	130
16	.051	133	4.12	21.74	8	41	16	83	20	105

COPPER-CLAD WIRE—GRADE "A"
Bright, Hard Drawn

Number B. & S. Gauge	Diameter Bare Wire in In.	Breaking Weight in Pounds	Resistance in Ohms at 60° F.		Weight in Pounds					
					Bare Wire		Double Braid Weatherproof		Triple Braid Weath'rproof	
			Per 1000 Ft.	Per Mile	Per 1000 Ft.	Per Mile	Per 1000 Ft.	Per Mile	Per 1000 Ft.	Per Mile
0	.325	5472	.32	1.70	293	1546	350	1850	381	2011
1	.289	4798	.41	2.14	232	1226	273	1443	295	1560
2	.258	3804	.51	2.70	184	972	223	1177	243	1283
4	.204	2721	.81	4.29	116	611	140	740	153	810
6	.162	1797	1.29	6.82	73	384	94	494	105	555
8	.128	1187	2.05	10.84	46	242	62	327	71	373
9	.114	984	2.59	13.68	36	192	51	266	58	308
10	.102	780	3.26	17.24	29	152	43	227	51	266
12	.081	512	5.20	27.43	18	96	28	149	33	176
14	.064	334	8.25	43.60	11	60	19	101	24	127
16	.051	216	13.14	69.40	7	38	15	80	19	102

NOTE.—Average conductivity, 30 per cent. Minimum conductivity, 27 per cent.

CONTROL WIRES FOR SWITCH AND SIGNAL FUNCTIONS

Determination of the Required Size of Wire for a Given Length of Control

Function	Oper. Current	Holding Current	Oper. Time with Max. Length Control	Max. Length Control (See Note) Number of Wire, B. & S. Gauge							
				No. 16	No. 14	No. 12	No. 10	No. 9	No. 8	No. 6	No. 4
	Amp.	Amp.	Seconds	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
High Signal, Model 2, ...	3.0	.14	4	1600	2600	4160	6600	8250	10400	16650	26500
High Signal, Model 3 or 7, ...	3.0	.11	3	1600	2600	4160	6600	8250	10400	16650	26500
High Signal, Model 2A,.	.82	.25	6	5360	8530	10360	22500	27000	34000	55000	86500
Dwarf Signal, Model 2A, ...	.82	.25	4	5360	8530	10360	22500	27000	34000	55000	86500
Dwarf Signal, Model 2 or 3,.	4.0	.17	1	1900	3080	4820	8000	9650	12100	19500	34000
Switch Machine, Model 2, Switch or Derail, ...	6.0	...	2	640	1040	1665	2640	3300	4150	6700	10600
Switch Machine, Model 2, Double Slip or M. P. Frog,.	10.0	...	2.2	395	625	1000	1580	1980	2500	4000	6350
Switch Machine, Model 4A, Switch or Derail,.	4.5	...	3	1070	1730	2700	4500	5425	6850	11100	17300
Switch Machine, Model 4A, Double Slip or M. P. Frog,.	7.0	...	3.2	950	1540	2400	4000	4825	6150	9760	15400
Switch Machine, Model 4B, Switch or Derail,.	4.5	...	3	1520	2410	3850	6070	7700	9660	15210	24530
Switch Machine, Model 4B, Double Slip or M. P. Frog,.	7.0	...	3.2	1410	2230	3560	5630	7130	8970	14090	22760

Note.— In above table the given lengths of control extend from positive buss through function to main common.

COMMON RETURN WIRE

Determination of the Required Size Wire for a Given Length of Common

Max. Amps. in Common	Number of Common Wire, B. & S. Gauge												Max. Amps. in Common
	14	12	10	9	8	6	4	2	1	0	00	000	
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	
4.5	503	802	1275	1600	2025	3220	5120	8140	10275	12950	16300	20550	4.5
6	378	603	956	1205	1521	2420	3850	6115	7710	9740	12250	15450	6
7	324	517	820	1032	1305	2075	3300	5245	6620	8350	10050	13250	7
9	254	404	640	807	1020	1620	2560	4100	5160	6525	8210	10350	9
10	227	361	575	724	913	1451	2310	3670	4630	5840	7350	9275	10
11.5	197	314	503	628	792	1260	2010	3190	4125	5075	6390	8500	11.5
13	174	278	441	555	701	1115	1772	2820	3560	4490	5650	7125	13
14	162	258	410	517	654	1040	1650	2620	3300	4170	5250	6625	14
16	142	226	359	453	570	907	1445	2295	2890	3650	4600	5800	16
18	126	202	318	410	507	806	1280	2040	2570	3240	4085	5150	18
20	113	181	287	362	456	726	1155	1835	2312	2920	3680	4630	20
22	103	164	261	329	415	660	1150	1670	2120	2660	3345	4215	22
24	94	151	239	301	380	605	963	1530	1930	2435	3060	3865	24
26	...	139	221	278	352	560	890	1412	1760	2250	2830	3562	26
28	...	129	205	258	326	518	824	1320	1650	2085	2620	3310	28
30	...	120	191	241	304	485	770	1223	1541	1950	2450	3090	30
32	...	...	179	226	285	455	724	1145	1445	1825	2300	2900	32
34	...	...	168	213	269	427	680	1080	1360	1720	2163	2730	34
36	...	...	160	201	254	405	644	1020	1290	1625	2045	2580	36
38	...	...	151	190	240	383	610	965	1220	1540	1935	2440	38
40	...	...	143	181	228	364	578	917	1158	1460	1840	2320	40
42	...	...	...	172	217	346	550	875	1101	1392	1755	2210	42
44	...	...	...	164	208	331	525	835	1053	1330	1672	2110	44
46	...	...	...	157	198	315	500	795	1003	1265	1595	2010	46
48	...	...	...	151	190	303	481	765	965	1215	1532	1931	48
50	...	...	...	145	182	290	462	734	925	1170	1470	1855	50
52	...	...	...	...	175	279	443	703	887	1120	1410	1775	52
54	...	...	...	...	169	269	427	680	855	1070	1360	1715	54
56	...	...	...	...	163	259	412	655	825	1040	1312	1655	56
58	...	...	...	...	157	250	398	633	798	1010	1270	1600	58
60	...	...	...	...	152	242	385	612	770	975	1225	1545	60
62	...	...	...	...	...	235	373	594	747	945	1188	1500	62
64	...	...	...	...	...	227	362	575	725	915	1150	1450	64
66	...	...	...	...	...	220	350	556	700	886	1130	1405	66
68	...	...	...	...	...	213	338	539	679	856	1080	1360	68
70	...	...	...	...	...	207	329	524	661	835	1050	1325	70
72	...	...	...	...	...	201	320	510	643	810	1020	1286	72
74	...	...	...	...	...	196	312	495	625	788	992	1250	74
76	...	...	...	...	...	191	304	483	610	770	967	1226	76
78	...	...	...	...	...	186	296	471	594	750	945	1190	78
80	...	...	...	...	...	181	288	459	578	730	919	1160	80

Note.—To determine maximum return amperes in common wire, add the amperes taken by all functions *likely* to be operated at the same time.

RELATIVE COMPARISON OF COPPER AND ALUMINUM CONDUCTORS

Metal	Of Equal Length and Cross Section		Of Equal Length and Conductivity			
	Conductivity	Resistance	Cross Section	Weight	Tensile Strength	Cost
Copper	100	100	100	100.0	100.0	100
Aluminum	54	185	180	54.0	85.1	185
Aluminum	55	182	176	53.0	83.5	189
Aluminum	56	179	173	52.0	82.0	192
Aluminum	57	175	170	51.1	80.6	196
Aluminum	58	172	167	50.2	79.2	199
Aluminum	59	169	164	49.4	77.9	203
Aluminum	60	167	162	48.6	76.6	206
Aluminum	61	164	159	47.8	75.3	210
Aluminum	62	161	157	47.0	74.1	213
Aluminum	63	159	154	46.3	72.9	216

CARRYING CAPACITY OF INTERIOR CONDUCTORS

National Electrical Code

B. and S. Gauge Copper 98% Con.	Concealed Rubber Covered Wires	Exposed Weatherproof Wires
	Amperes	Amperes
0000	210	312
000	177	262
00	150	220
0	127	185
1	107	156
2	90	131
4	65	92
6	46	65
8	33	46
9	28	38
10	24	32
12	17	23
14	12	16
16	6	8

Note.— Permissible heating only considered in above figures.

DIMENSIONS OF RAILWAY SIGNAL ASSOCIATION STANDARD RUBBER-COVERED COPPER WIRE

Size of Wire B. & S. Gauge	Diameter of Wire Inch	Thickness of Insulation Inch	Thickness of One Braid Inch	Total Diameter Inch
0	21/64	8/64	2/64	41/64
1	19/64	8/64	2/64	39/64
2	17/64	8/64	2/64	37/64
4	13/64	6/64	2/64	29/64
6	10/64	6/64	2/64	26/64
8	8/64	6/64	2/64	24/64
9	7/64	5/64	2/64	21/64
10	6/64	5/64	2/64	20/64
12	5/64	5/64	2/64	19/64
14	4/64	5/64	2/64	18/64
16	3/64	4/64	2/64	15/64

NOTE.—For each additional braid add four sixty-fourths inches to total diameter. For each layer of tape add two sixty-fourths inches to total diameter.

DIMENSIONS OF MANUFACTURER'S ENGINEERS' STANDARD RUBBER-COVERED COPPER WIRE

Size of Wire B. & S. Gauge	Diameter of Wire Inch	Thickness of Insulation Inch	Thickness of One Braid Inch	Thickness of One Tape Inch	Total Diameter
0	21/64	8/64	2/64	1/64	43/64
1	19/64	8/64	2/64	1/64	41/64
2	17/64	8/64	2/64	1/64	39/64
4	13/64	6/64	2/64	1/64	31/64
6	10/64	6/64	2/64	1/64	28/64
8	8/64	6/64	2/64	1/64	26/64
9	7/64	5/64	2/64	1/64	23/64
10	6/64	5/64	2/64	1/64	22/64
12	5/64	5/64	2/64	1/64	21/64
14	4/64	5/64	2/64	1/64	20/64
16	3/64	4/64	2/64	1/64	17/64

NOTE.—For each additional braid add four sixty-fourths inches to total diameter. For each additional layer of tape add two sixty-fourths inches to total diameter.

TRUNKING, JUNCTION BOXES AND SUPPORTS

EXTRACT FROM R. S. A. SPECIFICATION FOR ELECTRIC INTERLOCKING (1910)

700. TRUNKING

Material.

(*f*) Trunking, when on stakes above ground and running parallel with the track, shall not be placed nearer than six (6) feet from the gauge side of the nearest rail except by special permission.

(*g*) Local conditions shall determine the height of trunking when above ground; in general, when trunking is run parallel with the tracks, bottom of trunking shall be placed approximately six (6) inches above ground.

(*i*) Nails shall not be driven through the trunking from the inside of the groove nor shall they be driven into the groove from the outside.

(*j*) Inside corner of trunking, at turns, must be rounded to prevent insulation on wires being injured.

(*k*) Surfaces of trunking that are to be painted shall be finished.

(*l*) Not less than one-third (⅓) of the capacity of the groove shall remain free for the further installation of wires.

(*n*) As specified, capping shall be securely fastened to trunking with $\left\{\begin{matrix}\text{gate hooks}\\ \text{nails.}\end{matrix}\right\}$ Gate hooks may be used on main runs of trunking and nails on cross leads.

703. JOINTS IN TRUNKING

(*a*) Unless otherwise specified, joints in grooved trunking shall be lapped, the ends of trunking being beveled at an angle of forty-five (45) degrees.

(*b*) Joints in built-up trunking shall be staggered.

(*c*) Joints in capping shall be made at least one (1) foot from joints in trunking.

705. TRUNKING SUPPORTS

Material.

(*a*) Stakes shall be made of .... three (3) inches by four (4) inches, or of equivalent circular section and of sufficient length to allow them to be placed at least two (2) feet in the ground. When, due to local requirements, stakes of a greater length than three (3) feet six (6) inches, or a greater cross section than three (3) inches by four (4) inches will be necessary, information as to the number, length, and cross section will be furnished by the Purchaser to the Contractor.

Field work.

(*b*) Trunking above ground shall be supported on stakes placed not more than five (5) feet centers.

(*d*) Stakes supporting trunking shall be placed vertically and extend at least two (2) feet below the surface of the ground, unless otherwise specified.

(*e*) A piece of capping eight (8) inches long and the width of the trunking shall be placed between the trunking and each stake.

(*f*) Each joint in the bottom of the trunking shall be supported by a stake.

710. Junction Boxes

Material.

(*a*) Junction boxes shall be made of .... and so designed that terminals will be kept dry. Each junction box shall be fitted with a cover, hasp, and staple.

(*b*) Where ten (10) or less wires are used, junction boxes shall be sixteen (16) inches square by twenty (20) inches deep, inside dimensions, and shall be increased six (6) inches in length for each ten (10) additional connections or fraction thereof made in the box.

Field work.

(*c*) Junction boxes shall be located as shown on...... ....drawing .... and at a height sufficient to allow terminals to be placed at least six (6) inches above top of trunking.

(*d*) Junction boxes shall be supported in the same manner as the trunking.

TABLE FOR DETERMINING REQUIRED SIZE OF TRUNKING

Trunking			Rubber-Covered Copper Wire R. S. A. Specifications										
Size See Fig. 270	Size of Groove Inches	Area of Groove Sq. in.	No. 0	No. 1	No. 2	No. 4	No. 6	No. 8	No. 9	No. 10	No. 12	No. 14	No. 16
1	1 x 1	1.00	1	1	1	2	3	3	4	5	5	5	7
2	1¼ x 1½	1.87	2	2	3	5	6	6	8	9	9	10	14
3	1 x 2	2.00	2	2	3	5	6	7	9	10	10	11	15
4	1½ x 1½	2.25	2	3	3	6	7	8	10	11	11	12	17
5	1½ x 1¾	2.62	2	3	4	6	8	9	12	13	13	14	19
6	1½ x 2	3.00	3	4	4	7	9	10	13	14	15	16	22
7	1¾ x 1¾	3.06	3	4	5	7	9	10	14	14	15	16	22
8	2 x 2	4.00	4	5	6	10	12	13	17	18	19	21	28
9	1½ x 3	4.50	4	6	7	11	13	15	20	21	23	24	33
10	2 x 3	6.00	6	8	9	15	18	21	27	28	30	33	44
11	2 x 4	8.00	8	10	12	19	23	27	35	37	39	42	57
12	2 x 6	12.00	12	15	18	29	35	40	53	56	59	64	86

Note.— Table based on wires filling trunking to 75 per cent. of its maximum capacity.

TABLE FOR DETERMINING REQUIRED SIZE OF CONDUIT

Conduit		Rubber-Covered Copper Wire. R. S. A. Specifications										
Inside Diam. Inch	Area Inside Sq. In.	No. 0	No. 1	No. 2	No. 4	No. 6	No. 8	No. 9	No. 10	No. 12	No. 14	No. 16
1	.785	1	1	1	2	2	2	3	3	4	4	5
1½	1.77	2	2	2	4	5	5	7	8	8	9	12
2	3.14	3	3	4	7	8	10	12	13	14	15	21
2½	4.91	4	5	7	11	13	15	20	21	22	24	32
3	7.07	6	8	10	16	19	22	28	30	32	35	47
3½	9.62	9	11	13	21	26	30	38	41	43	47	63
4	12.57	11	14	18	28	34	39	50	54	56	62	83

Note.— Table based on wires filling conduit to 75 per cent. of its maximum capacity.

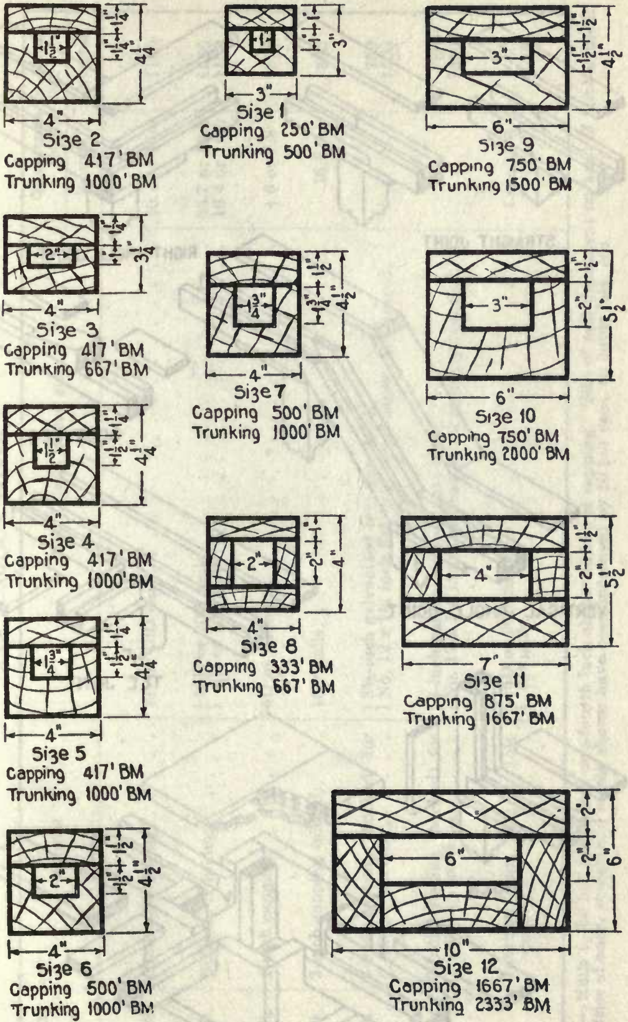


Fig. 270. Trunking Sections

Dimensions as shown are for rough sawed trunking and capping before surfacing. To determine finished dimensions deduct one-eighth inch from each side to be surfaced. Amounts of board feet are for 1,000 lineal feet.

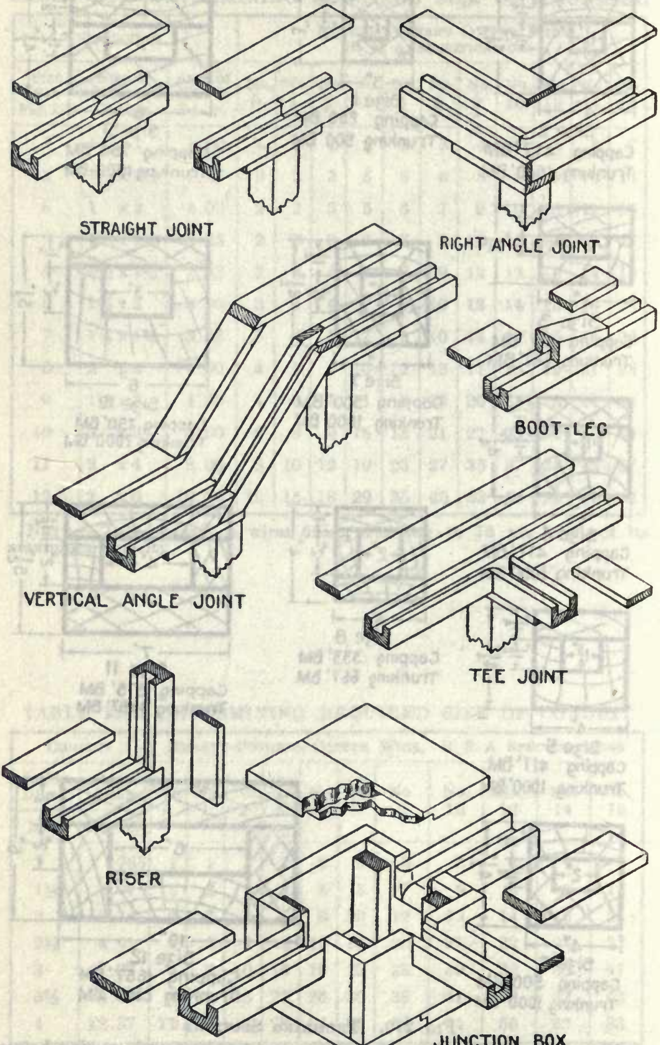


FIG. 271. TRUNKING AND JUNCTION BOX CONSTRUCTION

QUANTITIES OF NAILS, SCREWS, ETC., REQUIRED IN CONSTRUCTION OF TRUNKING AND JUNCTION BOXES

Quantity of Material	Material	Size of Nails, Hooks, etc.	Quantities of Nails, Hooks, Etc.	
			Pounds	Number
1000 ft.	Grooved trunking, ...	8D or 10D nails, ...	10.4 or 16.0	1100
1000 ft.	Built-up trunking, ...	16D or 20D nails, ... 8D or 10D nails, ...	33.7 or 53.3 10.4 or 16.0	1650 1100
1000 ft.	1-inch capping, ...	6D or 8D nails, ...	4.6 or 7.8	825
1000 ft.	2-inch capping (nailed), . .	16D nails.	16.8	825
1000 ft.	2-inch capping (hooked) for groved trunking, ...	3½-inch galvanized iron gate hook, ... No. 12 x 1¼ inch flat head wood screw, galvanized, .		750 1500
1000 ft.	2-inch capping (hooked) for built-up trunking, ...	4-inch galvanized iron gate hook, ... No. 12 x 1½ inch flat head wood screw, galvanized, .		750 1500
1	Junction Box 15½ x 15½ inches, ...	16D or 20D nails, ... 6D nails, ...	1.0 or 1.6 .14	50 25

NOTE.—Nails to be left projecting one-fourth inch above surface of capping. Size of nail dependent on kind of lumber used. Quantities of nails, screws and hooks shown have been increased by 10 per cent. to cover loss, etc.

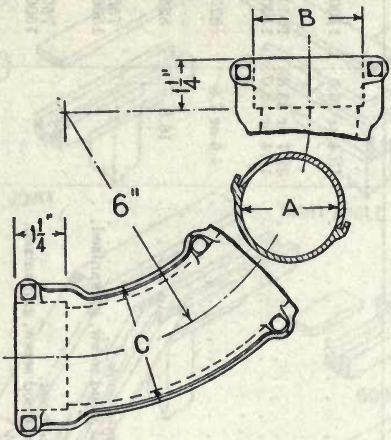


FIG. 272. G. R. S. SPLIT ELBOW FOR CONDUIT

DIMENSIONS OF SPLIT ELBOW

Size Conduit	Dimensions		
	A	B	C
Inch	Inch	Inch	Inch
2	2 1/16	2 7/16	2 5/8
2 1/2	2 15/32	2 15/16	3 1/32
3	3 1/16	3 9/16	3 5/8

PORTLAND CEMENT CONCRETE

COVERING DESCRIPTION OF CLASSES OF CONCRETE, METHODS OF MIXING, AND TABLES OF VOLUMES OF MATERIALS REQUIRED

PORTLAND CEMENT CONCRETE

Storing

In storing cement, wooden blocks should be placed on the floor and covered with boards; the bags of cement should be piled on this to a depth of six or eight layers, keeping the piles six or eight inches away from the walls of the building so as to obtain a free circulation of air on all sides. The cement should be covered with canvas or roofing paper.

The place chosen for storing the cement should be as dry as possible, as cement absorbs moisture from the atmosphere with great readiness, soon becoming lumpy or even a solid mass if the storehouse is at all damp. In this condition it is useless and should be thrown away. Lumps caused by pressure while being stored must not be mistaken for cement that has been wet and has then hardened; lumps caused by pressure are easily broken, the cement being perfectly good.

Portland cement is shipped in paper bags or cloth sacks, the second means being recommended as best for the average user.

Proportions of Materials for Concrete

A *Rich Mixture*, with proportions of 1 : 1½ : 3, is used for columns or other structural parts subjected to high stresses or requiring exceptional water-tightness.

A *Standard Mixture*, with proportions of 1 : 2 : 4, is used for reinforced floors, beams, and columns, for arches, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits and other water-tight work.

A *Medium Mixture*, with proportions of 1 : 2½ : 5, is used for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks and sewers with heavy walls.

A *Lean Mixture*, with proportions of 1 : 3 : 6 and 1 : 4 : 8, is used for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load and for stone masonry backing.

Consistency of Concrete

A *Medium or Quaking Mixture*, of a tenacious, jelly-like consistency which quakes on ramming, shall be used for ordinary mass concrete, such as foundations, heavy walls, large arches, piers and abutments.

A *Wet or Mushy Concrete*, so soft that it will not require ramming, shall be used for rubble concrete, and for reinforced concrete, such as thin building walls, columns, doors, conduits and tanks.

A *Dry Concrete*, of the consistency of damp earth, may be employed in damp locations for mass foundations, which must stand severe compressive strain within one month after placing, providing it is spread in six inch layers and rammed until water flushes to the surface. Dry mixed concrete shall never be employed with steel reinforcement.

Mixing Concrete by Hand

For mixing concrete by hand, a water-tight platform is recommended on which is first spread the sand and then the required amount of cement. Two or more laborers, an even number working on each side of the board, should systematically turn the cement into the sand with a slight "flip" on leaving the shovel, being sure to cut to the bottom of the pile at each stroke. This operation will have moved the location of the pile about two feet. Reversing the direction of the operation brings the pile to its original position, but in a mixed condition. By cutting into the pile with a shovel, an idea of the uniformity of mixing can easily be obtained; the appearance of streaks indicates the need for another turning. If the mixture is of uniform color, the required amount of stone may be distributed over the pile, which should be turned in the same manner until thoroughly mixed. Water is then added and the mass again turned until the desired consistency is secured.

Mixing Concrete by Machine

Recent experiments conducted on the strength of machine concrete mixed for varying periods indicate that the materials must remain in agitation with the water for at least a full minute. The tendency to rush work is not productive of good concrete, and should, consequently, be curbed. In general, machine mixing where carefully controlled is superior to hand work, since fatigue of the workman has no influence upon the thoroughness of mixing.

Cautions

On adding water to the dry cement it becomes a soft, sticky paste, and will remain so for about one-half hour, after which it begins to harden or "set." To disturb the concrete after this initial set has started means a decided loss in strength, while to disturb it after the set is well under way means to destroy the concrete. It should, therefore, be remembered that Portland cement concrete must be placed in position within twenty or thirty minutes from the time after it is first wet.

A green cement mixture, which can be easily frozen at a temperature below 32 degrees Fahr., should be protected from exposure by placing canvas or roofing paper over the form and covering this with four or five inches of earth or straw. Freezing does not materially affect the binding qualities of good Portland cement, provided the concrete is not subjected to alternate freezing and thawing, does not freeze until after placing, and is not subjected to any load until it has been thawed out and allowed to "set" in the usual way. It is safest to avoid mixing on days when the temperature is below the freezing point, that is 32 degrees Fahr. If it is necessary, however, to make concrete under these conditions, the sand, water and stone should be heated, and if the cold is severe, salt should be added in proportions of two pounds to each cubic yard of concrete.

EDITOR'S NOTE

Above article based on data furnished by Universal Portland Cement Company.

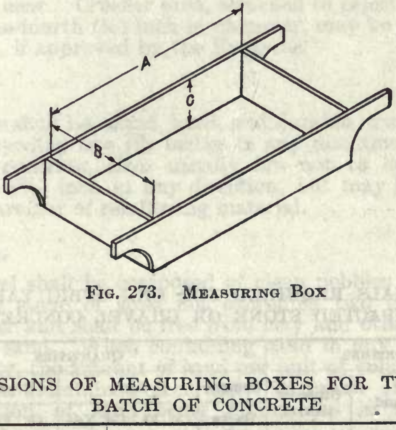


FIG. 273. MEASURING BOX

DIMENSIONS OF MEASURING BOXES FOR TWO BAG BATCH OF CONCRETE

Proportions			Size of Measuring Box					
			Sand			Stone or Gravel		
Cement (2 bags)	Sand	Stone or Gravel	A	B	C	A	B	C
			Ft. In.	Ft. In.	In.	Ft. In.	Ft. In.	In.
1	1½	3	3–0	2–0	6	3–0	2–0	12
1	2	3	4–0	2–0	6	3–0	2–0	12
1	2	4	4–0	2–0	6	4–0	2–0	12
1	2½	4	4–0	2–6	6	4–0	2–0	12
1	2½	5	4–0	2–6	6	4–0	2–6	12
1	3	5	4–0	3–0	6	4–0	2–6	12
1	3	6	4–0	3–0	6	4–0	3–0	12

VOLUME OF COMPACTED STONE OR GRAVEL CONCRETE PER SACK OF CEMENT

Proportions			Quantities			
Cement	Sand	Gravel or Stone	Cement Sacks	Sand Cu. Ft.	Gravel or Stone Cu. Ft.	Concrete Cu. Ft
1	1½	3	1	1.5	3.0	3.52
1	2	3	1	2.0	3.0	3.90
1	2	4	1	2.0	4.0	4.48
1	2½	4	1	2.5	4.0	4.85
1	2½	5	1	2.5	5.0	5.45
1	3	5	1	3.0	5.0	5.80
1	3	6	1	3.0	6.0	6.40

MATERIALS REQUIRED FOR ONE CUBIC YARD OF COMPACTED STONE OR GRAVEL CONCRETE

Proportions			Quantities				
			Cement	Sand		Stone or Gravel	
Cement	Sand	Stone or Gravel	Sacks	Cu. Ft.	Cu. Yds.	Cu. Ft.	Cu. Yds.
1	1½	3	7.64	11.5	.43	23.0	.85
1	2	3	6.96	13.9	.51	20.9	.77
1	2	4	6.04	12.1	.45	24.2	.90
1	2½	4	5.56	13.9	.51	22.2	.82
1	2½	5	4.96	12.4	.46	24.8	.92
1	3	5	4.64	13.9	.51	23.2	.86
1	3	6	4.24	12.7	.47	25.4	.94

Stone and gravel considered as having 45 per cent. voids.
Tables based on 1 sack cement = 1 cubic foot.
4 sacks cement = 1 barrel.
Above quantities may vary 10 per cent. in either direction, depending upon the materials used and the compactness of the concrete.

Data for above tables from the Universal Portland Cement Company.

R. S. A. SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE (1912)

1. General

These specifications are for making concrete as used in signal construction.

2. Cement

Cement shall be Portland, either American or Foreign, which will meet the requirements of the................ specifications.

3. Sand

Sand shall be clean, sharp, coarse, and of grains varying in size. It shall be free from sticks and other foreign matter, but it may contain clay or loam not to exceed five (5) per cent. Crusher dust, screened to reject all particles over one-fourth (¼) inch in diameter, may be used instead of sand, if approved by the Engineer.

4. Stone

Stone shall be sound, hard, and durable, crushed to sizes not exceeding two (2) inches in any direction. For reinforced concrete, sizes usually are not to exceed three-fourths (¾) inch in any direction, but may be varied to suit character of reinforcing material.

5. Gravel

Gravel shall be composed of clean pebbles of hard and durable stone of sizes not exceeding two (2) inches in diameter and shall be free from clay and other impurities except sand. When containing sand in any considerable quantity, the amount of sand per unit of volume of gravel shall be determined accurately, to admit of the proper proportion of sand being maintained in the concrete mixture.

6. Water

Water shall be clean and reasonably clear, free from sulphuric acid or strong alkalies.

7. Measure

The unit of measure shall be the barrel, which shall be taken as containing three and eight-tenths (3.8) cu. ft. Four (4) bags containing ninety-four (94) pounds of cement each shall be considered the equivalent of one (1) barrel. Fine and coarse aggregates shall be measured separately as loosely thrown into the measuring receptacle.

8. Density of Ingredients

(*a*) For pipe carrier foundations and reinforced concrete, a density proportion based on 1:6 is recommended, i. e., one (1) part of cement to a total of six (6) parts of fine and coarse aggregates measured separately.

(*b*) For signal and other foundations made in place a density proportion based on 1:9 is recommended, i. e., one (1) part of cement to a total of nine (9) parts of fine and coarse aggregates measured separately.

9. Mixing

(*a*) Tight platforms shall be provided of sufficient size to accommodate men and materials for progressive and rapid mixing. Batches shall not exceed one (1) cu. yd. and smaller batches are preferable.

(*b*) Spread the sand evenly upon the platform, then the cement upon the sand, and mix thoroughly until of an even color. Add all the water necessary to make a thin mortar and spread again; add the gravel if used, and finally the broken stone, both of which, if dry, should first be thoroughly wet down. Turn the mass with shovels or hoes until thoroughly incorporated, and all the gravel and stone is covered with mortar; this will probably require the mass to be turned four (4) times.

(*c*) Another approved method, which may be permitted at the option of the Engineer in charge, is to spread the sand, then the cement and mix dry, then the gravel or broken stone. Add water and mix thoroughly as above.

(*d*) A machine mixer may be used whenever the volume of work will justify the expense of installing the plant. The necessary requirements for the machine will be that a precise and regular proportioning of materials can be controlled and that the product delivered shall be of the required consistency and thoroughy mixed.

10. Consistency

The concrete will be of such consistency that when dumped in place it will not require much tamping. It shall be spaded down and tamped sufficiently to level off, and the water should rise freely to the surface.

11. Forms

(*a*) Where necessary, forms shall be well built, substantial and unyielding, properly braced, or tied together by means of wire or rods, and shall conform to lines given.

(*b*) For all important work, the lumber used for face work shall be dressed on one (1) side and both edges to a uniform thickness and width, and shall be sound and free from loose knots, secured to the studding or uprights in horizontal lines.

(*c*) For backings and other rough work undressed lumber may be used.

(*d*) Where corners of the masonry and other projections, liable to injury, occur, suitable moldings shall be placed in the angles of the forms to round or bevel them off.

(*e*) Lumber once used in forms shall be cleaned before being used again.

(*f*) The forms must not be removed within thirty-six (36) hours after all the concrete in that section has been placed. In freezing weather they must remain until the concrete has had a sufficient time to become thoroughly hardened.

(*g*) In dry, but not freezing, weather the forms shall be drenched with water before the concrete is placed against them.

12. DISPOSITION

(*a*) Each layer shall be left somewhat rough to insure bonding with the next layer above; and if it be already set, shall be thoroughly cleaned and scrubbed with coarse brushes and water before the next layer is placed upon it.

(*b*) Concrete shall be deposited in the molds in layers of uniform thickness throughout.

(*c*) The work shall be carried up in sections of convenient length and each section completed without intermission.

(*d*) In no case shall work on a section stop within eighteen (18) inches of the top.

(*e*) Concrete shall be placed immediately after mixing and any having an initial set shall be rejected.

13. FACING

(*a*) The facing will be made by carefully working the coarse material back from the form by means of a shovel bar or similar tool, so as to bring the excess mortar of the concrete to the face.

(*b*) About one (1) inch of mortar (not grout) of the same proportions as used in the concrete may be placed next to the forms immediately in advance of the concrete.

(*c*) Care must be taken to remove from the inside of the forms any dry mortar, in order to secure a perfect face.

14. FINISHING

(*a*) After the forms are removed, which should generally be as soon as possible after the concrete is sufficiently hardened, any small cavities or openings in the face shall then be neatly filled with mortar. The entire face shall then be washed with a thin grout of the consistency of whitewash, mixed in the same proportion as the mortar of the concrete. The wash shall be applied with a brush. The earlier the above operations are performed the better will be the result.

(*b*) The top surface of all crank, compensator, well hole, lock, dwarf, and high signal foundations shall be rubbed smooth by hand and shall be true to grade and line.

15. WATERPROOFING

Where waterproofing is required, a thin coat of mortar or grout shall be applied for a finishing coat upon which shall be placed a covering of suitable waterproofing material.

16. FREEZING WEATHER

Concrete to be left above the surface of the ground shall not be constructed in freezing weather, except by special instructions. In this case the sand, water and broken stone shall be heated, and in severe cold, salt shall be added in proportion of about two (2) pounds per cu. yd.

17. REINFORCED CONCRETE

Where concrete is deposited in connection with metal reinforcing, the greatest care must be taken to insure the coating of the metal with mortar, and the thorough compacting of the concrete around the metal. Whenever it is practicable the metal shall be placed in position first. This can usually be done in the case where the metal occurs in the bottoms of the forms, by supporting the metal on transverse wires, or otherwise, and then flushing the bottoms of the forms with cement mortar, so as to get the mortar under the metal, and depositing the concrete immediately afterward. The mortar for flushing the bars shall be composed of one (1) part cement and two (2) parts sand. The metal used in the concrete shall be free from dirt, oil, or grease. All mill scale shall be removed, by hammering the metal, or preferably by pickling the same in a weak solution of muriatic acid. No salt shall be used in reinforced concrete when laid in freezing weather.

SECTION XV

WRITTEN CIRCUITS

INCLUDING NOMENCLATURE OF OPERATED UNITS, CIRCUITS, AND WIRES, WITH TYPICAL ILLUSTRATIONS

WRITTEN CIRCUITS

WRITTEN Circuits, as hereafter described, have been designed to overcome the faults in the old method of circuit drawing which developed upon attempting its application to large interlocking installations.

A circuit plan for an interlocking, drawn up by the old method, consisted of a track plan, more or less to scale, on which plan symbols of the various pieces of apparatus were shown, placed as far as possible in their proper relative positions; such points as should be electrically connected were joined by lines representing wires.

While this method has been of great value in the past and still remains so for typical circuits, automatic signal work and small interlocking plants, the plans run into such size when used for large interlocking installations as to practically prohibit its use in connection with that class of work.

It is true, furthermore, that a great deal of unnecessary labor is involved in both drawing and deciphering the circuits. For example: The engineer in drawing up such a plan begins with some simple sketches, perhaps using symbols of his own invention. After carefully checking these circuits and assuring himself of their correctness, he converts them into the rather elaborate form described above, in which the attempt to keep down the size of the plan is very apt to result in a cramped arrangement of apparatus and a tangle of wires. When the man on maintenance or installation wishes to make use of these circuits, he has to reverse the process and reduce the composite drawing to its simple elements.

Written circuits have been designed to eliminate this unnecessary work and especially to secure plans in which the complete circuit for any given switch, signal, or other function, can be written on a page of ordinary size without crowding, these pages being bound together in a book which will easily and instantly permit reference to be made to any portion of the wiring of the plant.

A set of plans drawn up in accordance with this method involves the following:

1. *Location Plan.* This shows the relative location of track, interlocking station, switch and signal functions, track relays, switch circuit controllers, etc. Notes, such as for the routing of signal arms, should be included on this plan.

2. *Typical Plan of Special Circuits.* This shows what is proposed to be accomplished in route locking, etc., these circuits to be drawn up either by the old method, or in "written" form, as desired.

3. *Typical Plans of Signal Circuits, Switch Circuits, etc.*

4. *Special Circuits, made up in "written" form.* These special circuits are separated so that circuits not connected together are kept entirely apart from each other, being drawn

up on separate sheets. This desirable feature causes the "written" circuits to be exceptionally clear and permits their being readily grasped.

5. *Detail Wiring Plans.* It may be helpful under certain conditions to add to the circuits listed above, detail plans showing the wiring for the indicator group and interlocking machine.

In drawing up such circuits it is necessary to use a nomenclature for naming the apparatus and to adopt symbols to be used in writing the circuits. A nomenclature of operated units and of circuits, which has been used for some time by the General Railway Signal Company and found thoroughly practicable is given on the following pages.

On page 337 is given a nomenclature of wires. It is to be understood that this is equally applicable to written circuits or to circuits drawn up by the older methods.

NOMENCLATURE OF OPERATED UNITS

A — *Approach Relay or Indicator.* With number as prefix, indicating number of principal signal up to which the approach section controlling same leads, as 10A.

B — *Positive Battery Wire.* Used alone where only one battery voltage is in use. When used with H as a suffix (BH) indicates 110 volt battery. When used with L as a suffix (BL) indicates low voltage battery. When more than one low voltage battery is used with different voltage, use number indicating voltage as further suffix, as BL–10, indicating 10 volt battery.

C — *Common Wire.* Used alone when only one common is in use. When used with H as a suffix (CH) indicates 110 volt common. When used with L as a suffix (CL) indicates low voltage common. When more than one high voltage or low voltage common is used, use numbers as further suffixes. (CH–1, CH–2, CL–1, etc.)

D — *Relay or Indicator Controlling the Ninety Degree Position or Distant Function of a Signal.* With prefix indicating the number of principal signal which it controls, as 10D, indicating relay or indicator controlling the ninety degree position of signal No. 10, or signal No. 10 if it is a distant signal in two position signaling.

E — *Special Relay or Indicator* (other than T, D, H, K, or F relays and indicators). With number as prefix indicating number of principal unit entering into its control, or indicating principal unit which it controls.

F — *Relay or Indicator Repeating a Track Relay or Signal.* With number as a prefix indicating number of relay or signal which it repeats, as 10F.

FP — *Floor Push.*

G — *Switch Indicator.* With number of signal governing through block in which switch is located as prefix, as 10G.

H — *Relay or Indicator Controlling Forty-five Degree Position or Home Function of a Signal.* With prefix indicating the number of principal signal which it controls, as 10H, indicating relay or indicator controlling the forty-five degree position of signal No. 10, or signal No. 10 if it is a home signal in two position signaling.

J — *Junction Box or Terminal Board.* With arbitrary number as prefix, as 10J.

K — *Lock Relay.* Used in connection with route or detector locking for interrupting the current supply to switch and derail machines, etc., with number as a prefix, indicating track section affected by it, as 10K.

KS — *Knife Switch.*

L — *Lever Lock.* With prefix indicating number of lever which it locks, as 10L, meaning lock on lever No. 10.

LA — *Lightning Arrester.*

LC — *Latch Contact.* With prefix indicating number of lever, as 10LC.

M — *Man-hole.* With arbitrary number as prefix, as 10M.

PB — *Push Button or Strap Key.*

PC — *Pole Changing Relay.* With prefix indicating number of signal at which relay is located or number of signal controlled by it.

S — *Stick Relay.* Used in connection with route locking. With number as prefix, as 10S, meaning stick relay locking route of signal No. 10, or locking operated units in track section 10T, if separate stick relays are used for each track section.

SL — *Outlying Switch Lock.* With number as prefix indicating number of controlling lever. Use arbitrary number if there is no controlling lever.

T — *Track Circuit.* With number as prefix indicating number of track circuit, as 10T, which is also the name of the track relay for track circuit 10T.

Note.— The number for the track circuit is taken from the following in the order given:

M. P. Frog or
Switch or
Derail or
Arbitrary numbers 01, 02, 03, etc.

TL — *Traffic Lock.* With prefix indicating number of lever which it controls, as 10TL.

TP — *Telephone.*

TR — *Time Release.* With number as prefix indicating principal unit which it releases, as 10TR.

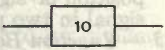
V — *Electric Slot.* With number of signal as prefix, as 10V.

XB — *Crossing Bell.* With arbitrary number as prefix, such as 10XB.

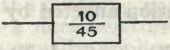
NOMENCLATURE OF CIRCUITS

Symbols for Operated Units

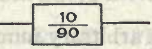
An operated unit (signal, relay, indicator, etc.) is represented by a rectangle with the number and letter of the relay, signal, etc., inside, thus:



The forty-five degree mechanism of a three-position signal is indicated thus:

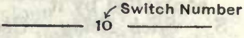


And the ninety degree thus:

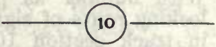


Circuit Controllers Operated by Switch Points

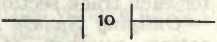
Closed when switch is normal, . . .



Closed when switch is reversed, . . .



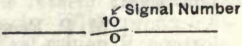
Closed when switch is normal and locked in position, ...



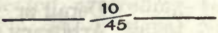
Closed when switch is reversed and locked in position, ...

Circuit Controllers Operated by Signals

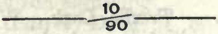
Closed at 0° only, ...



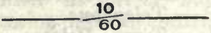
Closed at 45° only, ...



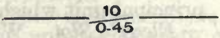
Closed at 90° only, ...



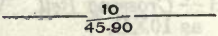
Closed at 60° only, ...



Closed between 0° and 45°, ...

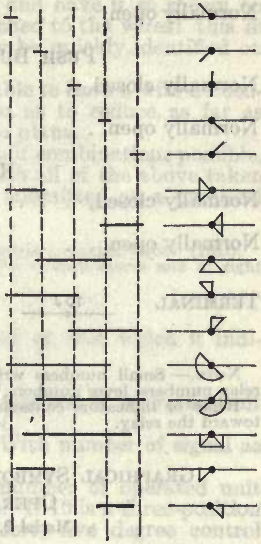


Closed between 45° and 90°, etc., . .



Circuit Controllers Operated by Levers

N B C D R Symbol



N—Full normal position of lever.

B—Normal indication position.

C—Intermediate position.

D—Reverse indication position.

R—Full reverse position.

Heavy horizontal line indicates portion of cycle of lever through which circuit is closed.

Relay and Indicator Contacts

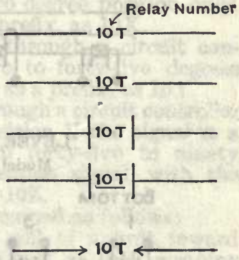
Neutral front contact, ...

Neutral back contact, ...

Normal polarized contact, ...

Reverse polarized contact, ...

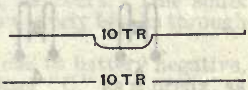
Intermediate contact on three-position relay: Closed when relay is deenergized, ...



Time Release Contact

Normally closed, ...

Normally open, ...



Latch Contact

Normally closed, ... 10 LC

Normally open, ... 10 LC

Push Button or Strap Key

Normally closed, ... PB

Normally open, ... PB

Knife Switch

Normally closed, ... KS

Normally open, ... KS

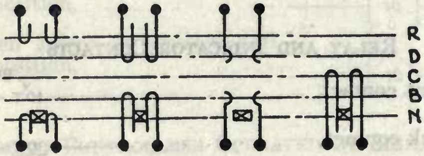
TERMINAL 10 J Meaning terminal in junction box No. 10 or on terminal board No. 10.

NOTE.— Small numbers written as exponents to the right and above relay numbers, lever numbers, etc., indicate contact numbers.

Relay or indicators contacts are numbered from left to right looking toward the relay.

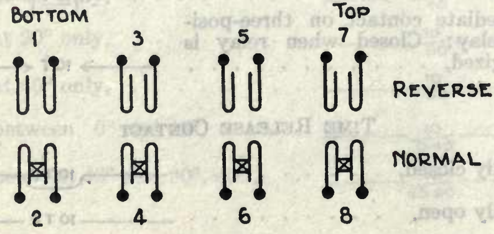
Graphical Symbols for Circuit Controllers Operated by Levers

Model 2, interlocking machine.



Lever Contact Numbering

Model 2, interlocking machine.



NOMENCLATURE OF WIRES

The matter of primary importance in naming wires is to have a different name for each wire and have it so shown on both the plan and suitable tags attached to the wires: this in order that a wire on the ground may be quickly identified on the plan.

At the same time it is highly desirable to have a wire nomenclature system that is suggestive, so as to reduce, as far as possible, the necessity for reference to plans.

On account of the multitude of circuit combinations possible, a system must be rather elastic. With all of the above taken into consideration, the following is submitted as a practical system of wire nomenclature.

NOTE.— Names of wires are shown on plans in brackets, thus: (10D). Number of cable containing a wire may be written above and at right angles to the wire, thus: 10

I — *Indication Wire.* With number of unit which it indicates as prefix, as 10I.

LL — *Lighting Wire.*

N — *Normal Control Wire.* With number of operated unit which it controls as prefix, as 10N.

P — *Ninety Degree Control Wire.* With number of signal as prefix, as 10P.

R — *Reverse Control Wire.* With number of operated unit which it controls as prefix, as 10R. If 10 is a three-position signal, 10R is the name of the forty-five degree control wire.

V — *Slot Wire.* With number of signal as prefix, as 10V.

X — Wire going to positive battery through a circuit controller on a signal closed in the zero degree position only, with the number of the signal as a prefix, as 10X.

Y — Wire going to positive battery through a circuit controller on a signal closed from zero to forty-five degrees only, with the number of the signal as a prefix, as 10Y.

Z — Wire going to positive battery through a circuit controller on a signal closed in the clear position if the signal is a two-position signal, or closed from forty-five to ninety degrees if the signal is a three-position signal, with the number of the signal as a prefix, as 10Z.

Wires not covered by the above are named as follows:

A wire leading from the operating coil of a unit toward battery positive takes the name of this unit, as 10H, meaning the wire from the coil of home control relay for signal No. 10 leading to positive. After passing through a circuit controller, it takes the number "1" as a suffix, as 10H1. This suffix number increases by one as the wire successively breaks through additional controllers.

The wire leading from the operating coil to battery negative, takes the name of the unit with the letter "C" as a prefix, as

C10H, and after breaking through successive controllers is written C10H1, C10H2, etc.

The above method applies directly to simple circuits having no branches, thus:

C — 16 F —(C10H1)— 18 F —(C10H)— [10 H] —(10H)— 17 F —(10H1)— 14 F — B

In cases of branch wiring this method is applied directly to the principal circuit — circuit for superior route. The first branch from this circuit takes the suffixes 21, 22, etc., instead of 1, 2, etc. The second branch 41, 42, etc., thus continuing allowing twenty numbers for each branch.

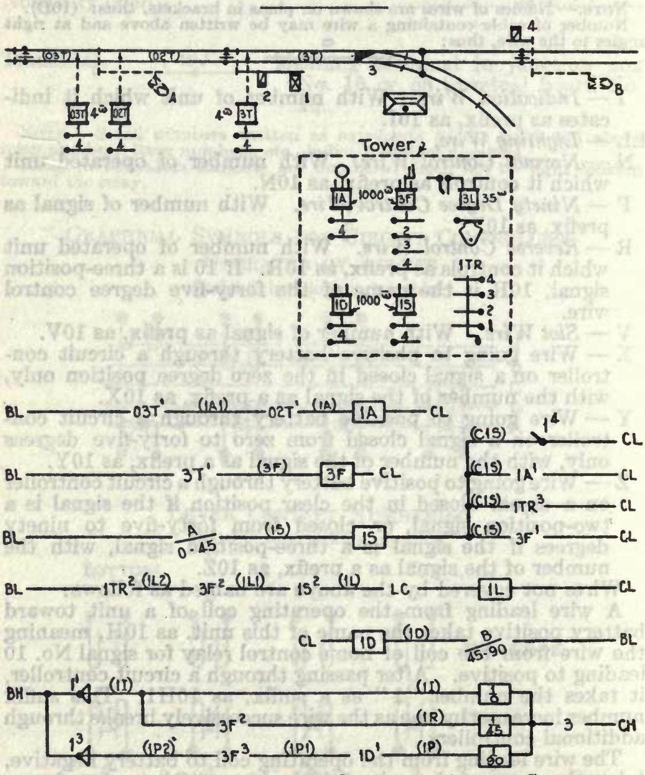


FIG. 274. SECTION OF LOCATION PLAN WITH SPECIAL CIRCUITS

ILLUSTRATIONS

Illustrative of "Written Circuits" and "Wire Nomenclature," is shown in Fig. 274, a section of an interlocking plant with the special circuits used in connection with such an arrangement. In accordance with the instructions given under "Location Plan" on page 331, the track plan with the relative location of signal and switch functions, track relays and the interlocking station with its indicators, relays, etc., is shown.

Below the track plan are shown the special circuits drawn up in written form. Referring to the sheets of nomenclature shown on the preceding pages, it will be seen that the circuit

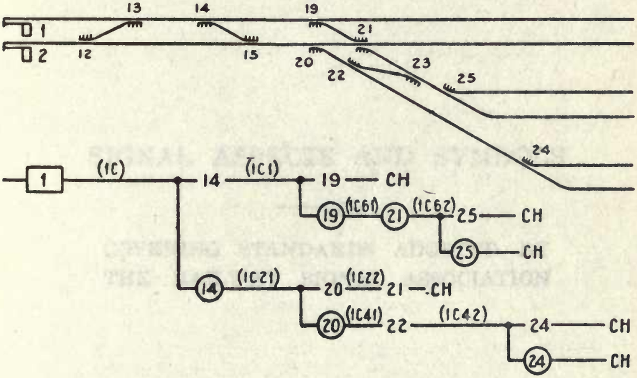


FIG. 275. SIGNAL SELECTING CIRCUIT

shown at the top is for the control of the annunciator for signal No. 1, this taking low voltage battery through front contacts of the track relays for sections 03T and 02T. Similarly the control of lock 1L takes battery through normally closed contact No. 2 of screw release 1TR, the front point of home relay 3F, the front point of contact No. 2 of stick relay 1S and the latch contact of the lock itself; the current after passing through the lock goes to the low voltage common wire. Information regarding the operation of this type of special circuit may be had by reference to the Section on "Electric Locking Circuits" (page 133).

Fig. 275 illustrates the method of writing a signal selecting circuit. This is included principally to show the application of the wire nomenclature to the different branches of the same circuit. The wires of each branch are designated in the same manner as in the principal circuit but with the suffixes 21, 22, 23, or 41, 42, 43, etc., these depending upon the order in which the different branches are taken from the principal circuit.

ILLUSTRATIONS

Illustrative of "Written Circuits" and "Wire Nomenclature," is shown in Fig. 274, a section of an interlocking plant with the special circuits used in connection with such an arrangement. In accordance with the instructions given under "Location Plan" on page 321, the track plan with the relative location of signal and switch functions, track relays and the interlocking station with its indicators, relays, etc., is shown.

Below the track plan are shown the special circuits drawn up in written form. Referring to the sheets of nomenclature shown on the preceding pages, it will be seen that the circuit

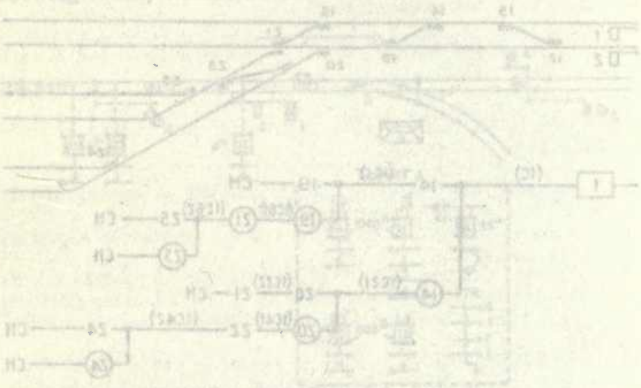


FIG. 275. SIGNAL SELECTING CIRCUIT

shown at the top is for the control of the annunciator for signal No. 1, this taking low voltage battery through front contacts of the track relays for sections 03T and 02T. Similarly the control of lock 11, takes battery through normally closed contact No. 2 of screw release 1TR, the front point of home relay 3E, the front point of contact No. 2 of stick relay 13 and the latch contact of the lock itself; the current after passing through the lock goes to the low voltage common wire. Information regarding the operation of this type of special circuit may be had by reference to the Section on "Electric Locking Circuits," (page 183).

Fig. 275 illustrates the method of writing a signal selecting circuit. This is included principally to show the application of the wire nomenclature to the different branches of the same circuit. The wires of each branch are designated in the same manner as in the principal circuit but with the suffixes 21, 22, 23, or 41, 42, 43, etc., these depending upon the order in which the different branches are taken from the principal circuit.

SIGNAL ASPECTS AND SYMBOLS

COVERING STANDARDS ADOPTED BY THE RAILWAY SIGNAL ASSOCIATION

SIGNAL ASPECTS AND SYMBOLS

R. S. A. PRINCIPLES OF SIGNAL INDICATIONS (1906)

(*a*) On all high signals conferring or restricting rights a red light shall be the night indication for STOP. A yellow light shall be the night indication for CAUTION, and a green light the night indication for PROCEED.

NOTE.—The word caution to be used as indicating the function of a distant signal.

(*b*) The day indication of semaphore signals shall be given in the upper right-hand quadrant.

(*c*) The semaphore arm in the horizontal position shall indicate STOP, inclined upward forty-five (45) degrees, CAUTION, and inclined upward, ninety (90) degrees, PROCEED.

SIGNALING PRACTICE AS DEFINED BY THE R. S. A. (1913)

MEMORANDUM ON THE ESSENTIALS OF SIGNALING

Incorporated in the Report of the Committee on Transportation of the American Railway Association, May, 1911.

"The reports of various Committees of the Railway Signal Association and of the American Railway Engineering Association on the subject of signaling have been submitted to this Committee, with the request that the essentials of signaling be outlined or defined for the future guidance of their Committees.

The subject has been carefully analyzed and considered. There are three signals that are essential in operation and therefore fundamental, viz:

1. Stop.
2. Proceed with caution.
3. Proceed.

The fundamental, "proceed with caution," may be used with the same aspect to govern any cautionary movement; for example, when:

(*a*) Next signal is "stop."
(*b*) Next signal is "proceed at low speed."
(*c*) Next signal is "proceed at medium speed."
(*d*) A train is in the block.
(*e*) There may be an obstruction ahead.

There are two additional indications which may be used where movements are to be made at a restricted speed, viz:

4. Proceed at low speed.
5. Proceed at medium speed.

Where automatic block system rules are in effect, a special mark of some distinctive character should be applied at the stop signal.

The Committee therefore recommends:

Signal Fundamentals

1. Stop.
2. Proceed with caution.
3. Proceed.

Supplementary Indications to be Used Where Required.

4. Proceed at low speed.
5. Proceed at medium speed.

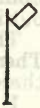
Stop signals operated under automatic block system rules should be designated by some distinctive mark to be determined by each road in accordance with local requirements."

Recommendations of Committee I

Your Committee submits for approval the following two schemes of signaling in conformity with the recommendations of the Committee on Transportation.

Scheme No. 1
Fundamentals

1. Stop, ... 

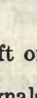
2. Proceed with caution, ... 

3. Proceed, ... 

As means of designating stop signals operated under automatic block system rules, the following are suggested:

1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

Scheme No. 2

	Fundamentals	Supplementary Indications
1. Stop, ...		. . . . . 
2. Proceed with caution, ...		. . . . 
3. Proceed, ...		. . . . 
4. Proceed at low speed, ...		
5. Proceed at medium speed, ...		

As means of designating stop signals operated under automatic block systems rules, the following are suggested:

1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

Having in view the practice of indicating diverging routes by several arms on the same mast, the Committee submits for approval the following to establish uniformity in this practice:

Scheme No. 3

1. Stop, ...  or  or  or 

2. Proceed with caution, ...  or  or 

3. Proceed, ...  or  or 

4. Proceed with caution on low-speed route, ...  or  or 

5. Proceed on low-speed route, . .  or  or 

6. Proceed with caution on medium-speed route, ... 

7. Proceed on medium speed route, 

8. Reduce to medium speed, . . .  or 

As means of designating stop signals operated under automatic block system rules, the following are suggested:

1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

The above three schemes are submitted, after an earnest effort to carry out the Committee's instructions to submit a uniform scheme of signaling, with the idea that each scheme is complete in itself.

SIGNAL DEFINITIONS

A "non-automatic" signal is one which is in no way controlled by track circuit.

An "automatic" signal is one, the primary control of which is the track circuit, or in other words, it is a signal which automatically gives indication in regard to the integrity of the track through its block.

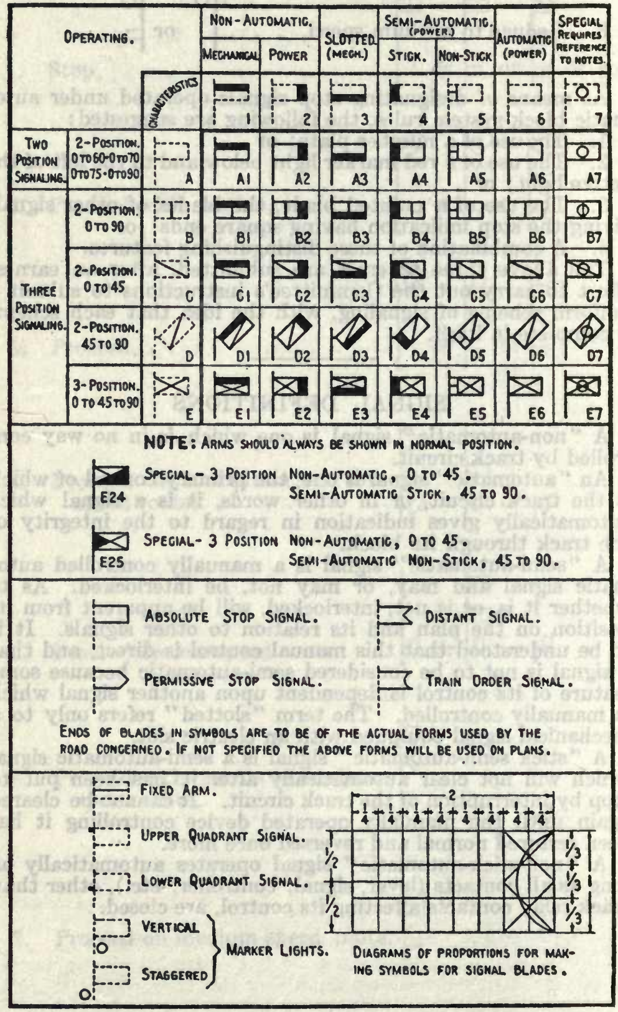
A "semi-automatic" signal is a manually controlled automatic signal and may, or may not, be interlocked. As to whether it is, or is not, interlocked, will be apparent from its position on the plan and its relation to other signals. It is to be understood that this manual control is direct, and that a signal is not to be considered semi-automatic because some feature of its control is dependent upon another signal which is manually controlled. The term "slotted" refers only to a mechanical signal equipped with an electric slot.

A "stick semi-automatic" signal is a semi-automatic signal which will not clear automatically after it has been put to stop by interruption of the track circuit. It cannot be cleared again until the manually operated device controlling it has been restored normal and reversed once more.

A "non-stick-automatic" signal operates automatically as long as all contacts (lever, signal, controller, etc.), other than track relay contacts affecting its control, are closed.

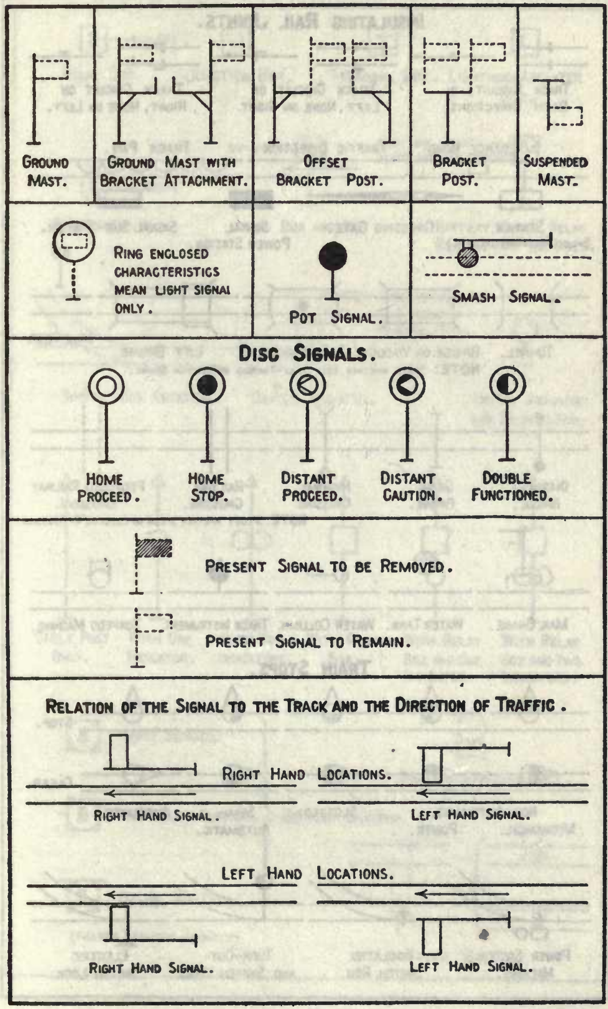
R. S. A. SYMBOLS FOR SIGNALS

Plate 1 (October, 1912).



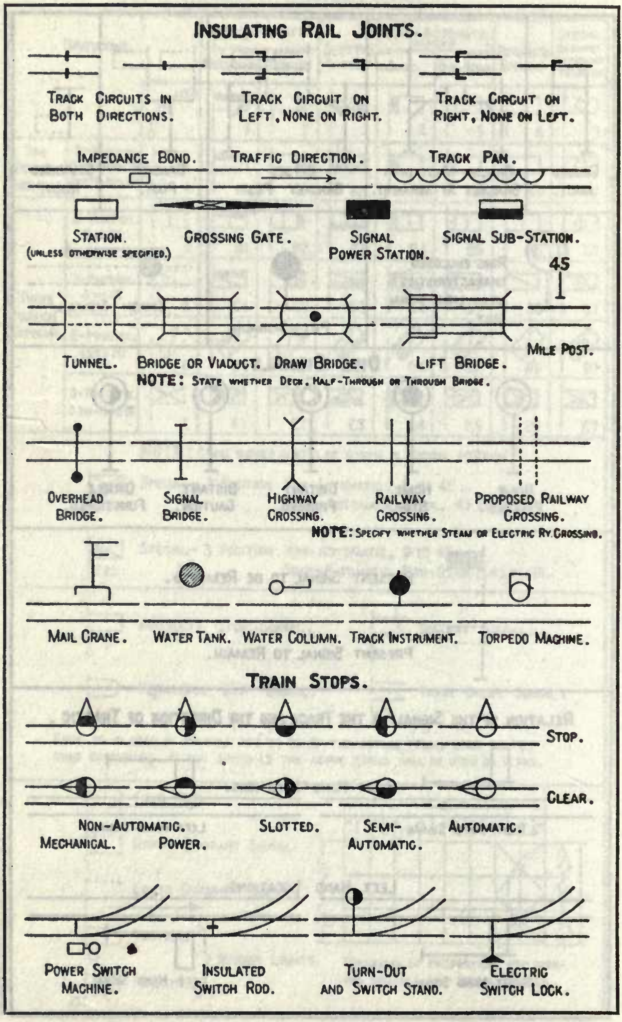
R. S. A. SYMBOLS FOR SIGNALS

PLATE 2 (October, 1912).



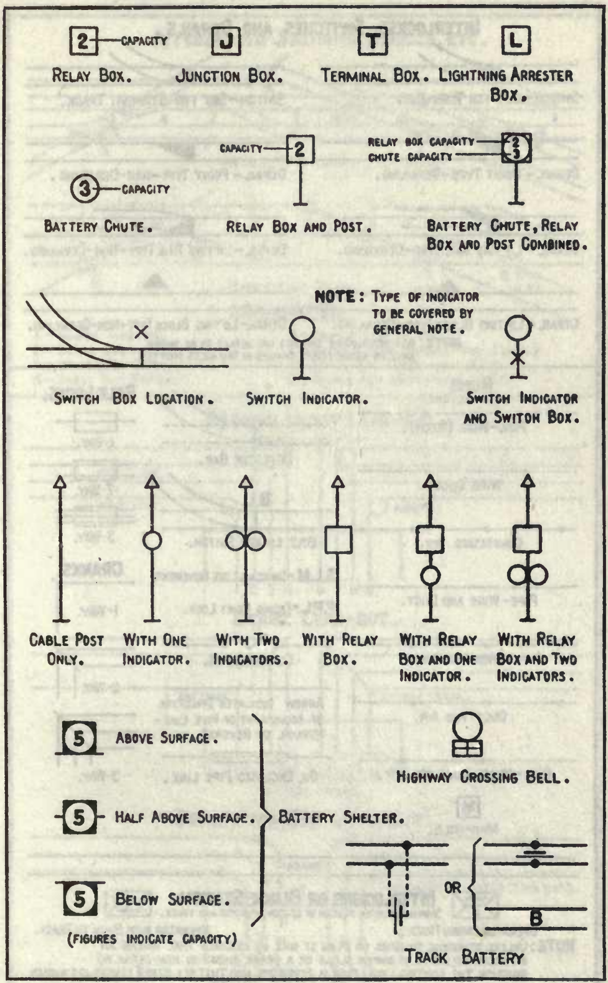
R. S. A. LOCATION SYMBOLS

PLATE 3 (October, 1912).



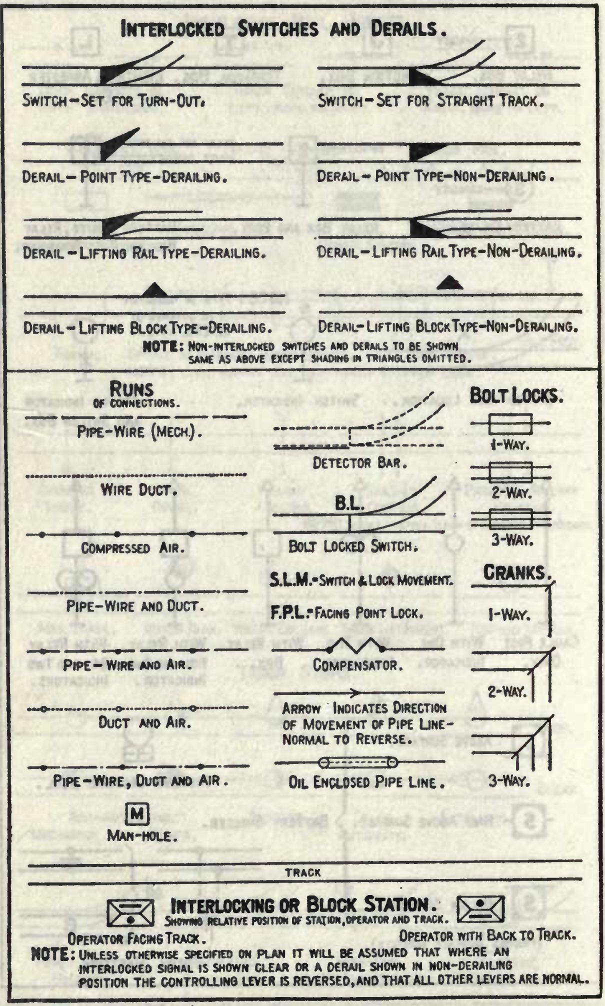
R. S. A. LOCATION SYMBOLS

PLATE 4 (October, 1912).



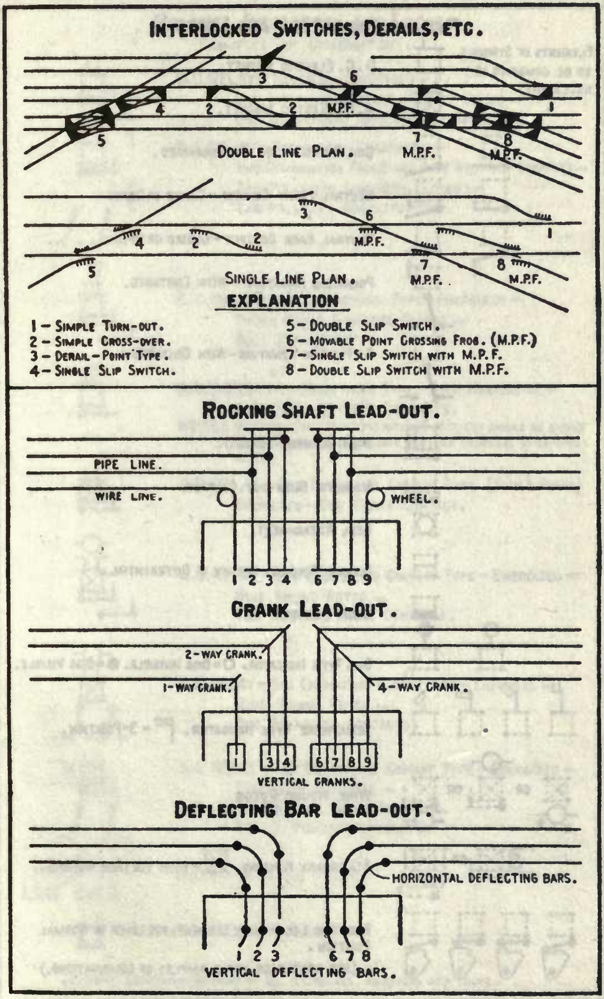
R. S. A. LOCATION SYMBOLS

PLATE 5 (October, 1912).



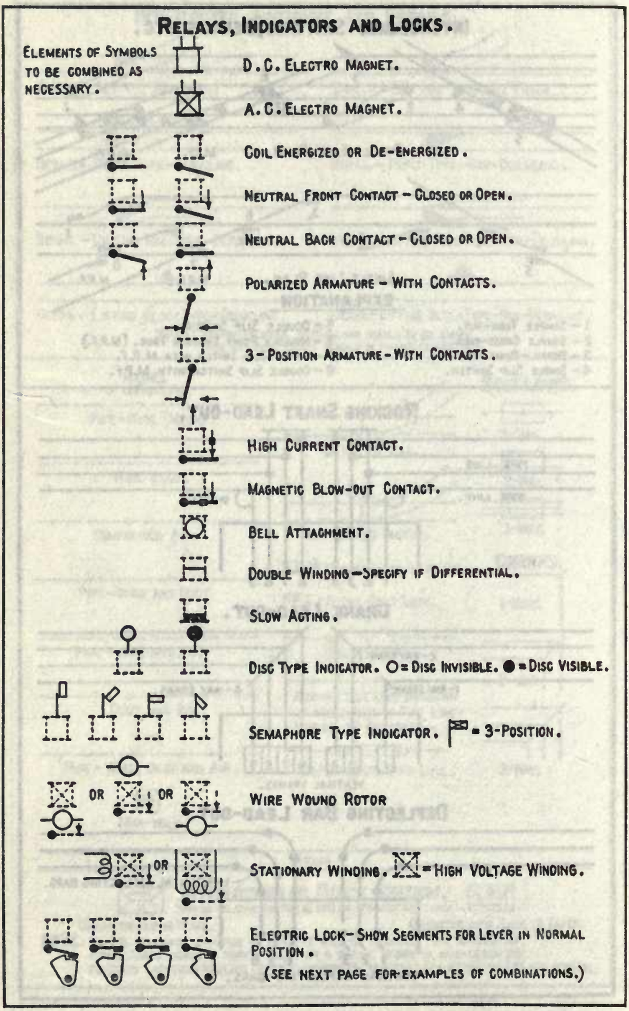
R. S. A. LOCATION SYMBOLS

PLATE 6 (October, 1912).



R. S. A. SYMBOLS FOR RELAYS, INDICATORS AND LOCKS

PLATE 7 (October, 1912).



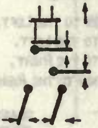
R. S. A. SYMBOLS FOR RELAYS, INDICATORS AND LOCKS

PLATE 8 (October, 1912).

RELAYS, INDICATORS AND LOCKS.

EXAMPLES OF COMBINATIONS.

D.C. RELAY – NEUTRAL – ENERGIZED –
ONE INDEPENDENT FRONT CONTACT CLOSED –
ONE INDEPENDENT BACK CONTACT OPEN.



D.C. RELAY – POLARIZED – ENERGIZED –
TWO COMBINATION FRONT AND BACK NEUTRAL CONTACTS –
TWO POLARIZED CONTACTS CLOSED –
TWO POLARIZED CONTACTS OPEN.

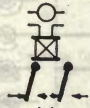
D.C. INDICATOR – SEMAPHORE TYPE – ENERGIZED –
THREE FRONT CONTACTS, CLOSED –
BELL ATTACHMENT.

D.C. INDICATOR – SEMAPHORE TYPE – ARM HORIZONTAL –
ENERGIZED – WITHOUT CONTACTS.

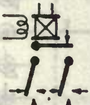
NOTE: INDICATORS (OR REPEATERS) WITHOUT CONTACTS SHOULD BE SHOWN WITH ARMATURES TO INDICATE WHETHER ENERGIZED OR DE-ENERGIZED.

A.C. RELAY – ONE ENERGIZING CIRCUIT TYPE (SINGLE PHASE)
ENERGIZED – ONE FRONT CONTACT.

A.C. RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
WIRE WOUND ROTOR –
TWO NEUTRAL FRONT CONTACTS.



A.C. RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
WIRE WOUND ROTOR –
TWO POLARIZED CONTACTS.



A.C RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
STATIONARY WINDINGS –
ONE NEUTRAL FRONT CONTACT –
TWO 3-POSITION CONTACTS.

D.C. INTERLOCKED RELAY.

D.C. ELECTRIC BELL.

DESIGNATE RESISTANCE IN OHMS OF ALL D.C. RELAYS, INDICATORS AND LOCKS.

R. S. A. SYMBOLS FOR CIRCUIT CONTROLLERS

PLATE 9 (October, 1912).

CIRCUIT CONTROLLERS OPERATED BY LEVERS.

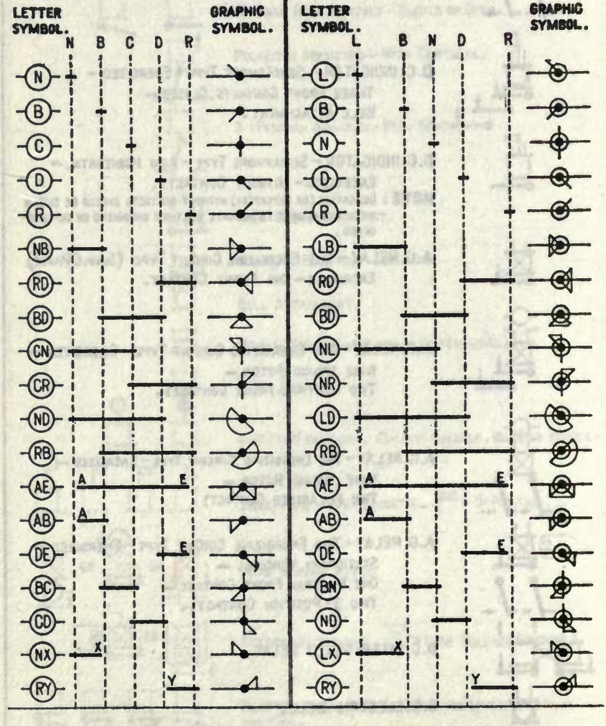
USE EITHER LETTER SYSTEM OR GRAPHIC SYSTEM.

LEVERS WITH EXTREME END POSITION AS NORMAL.

N-FULL NORMAL POSITION OF LEVER
B-NORMAL INDICATION POSITION.
C-CENTRAL POSITION.
D-REVERSE INDICATION POSITION.
R-FULL REVERSE POSITION.

LEVERS WITH MIDDLE POSITION AS NORMAL.

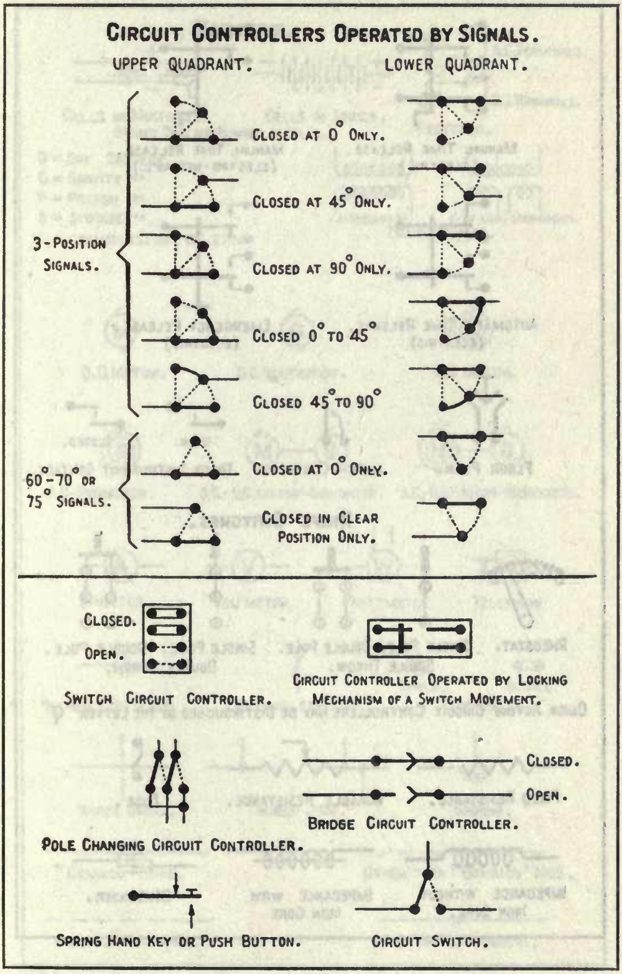
N-NORMAL POSITION.
L-FULL REVERSE POSITION TO THE LEFT.
B-INDICATION POSITION TO THE LEFT.
D-INDICATION POSITION TO THE RIGHT.
R-FULL REVERSE POSITION TO THE RIGHT.



NOTE: HEAVY HORIZONTAL LINES INDICATE PORTION OF CYCLE OF LEVER THROUGH WHICH CIRCUIT IS CLOSED

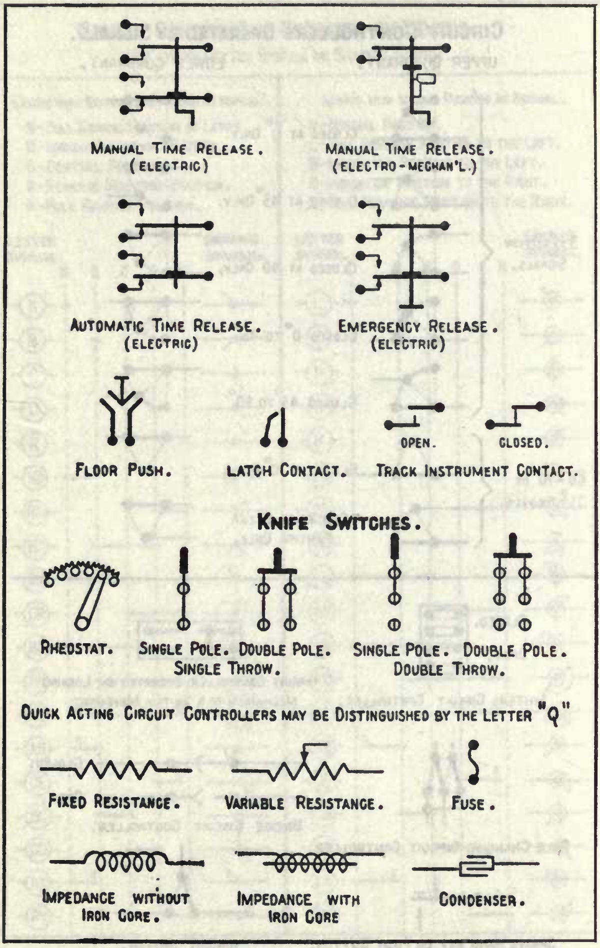
R. S. A. SYMBOLS FOR CIRCUIT CONTROLLERS

PLATE 10 (October, 1912).



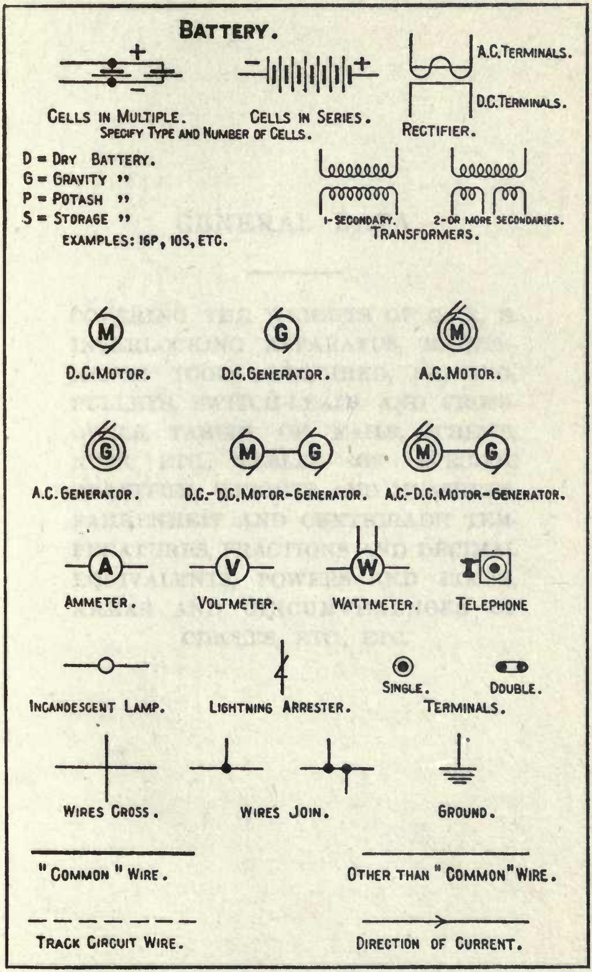
R. S. A. SYMBOLS FOR CIRCUIT CONTROLLERS, RELEASES, ETC.

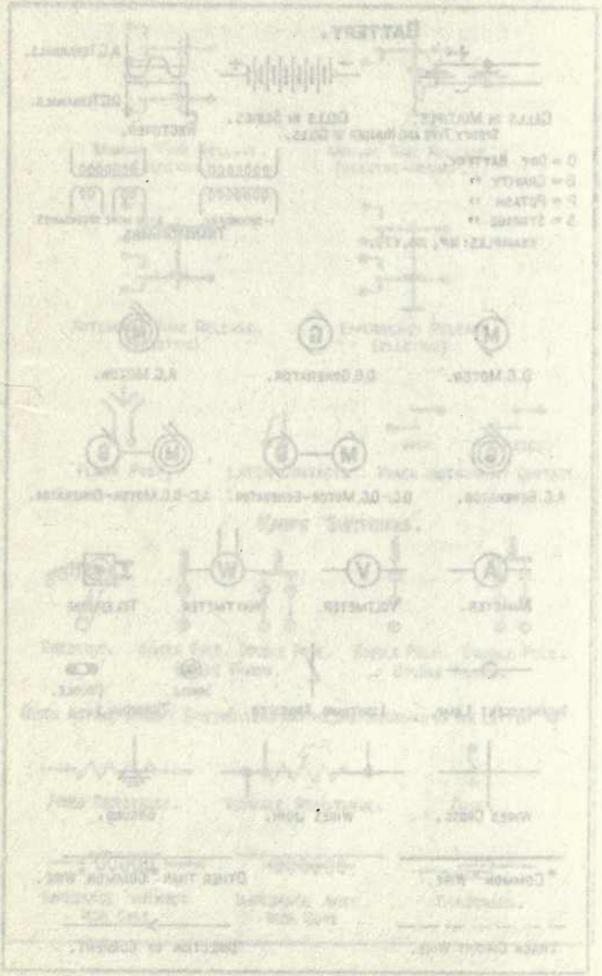
Plate 11 (October, 1912).



R. S. A. SYMBOLS FOR BATTERIES, GENERATORS, MOTORS, ETC.

PLATE 12 (October, 1912).




Emergency Release (Electric)
Manual Switches.

GENERAL DATA

COVERING THE WEIGHTS OF G. R. S. INTERLOCKING APPARATUS, MAINTENANCE TOOLS REQUIRED, BELTING, PULLEYS, SWITCH-LEADS AND CROSSOVERS, TABLES OF NAILS, SCREWS, NUTS, ETC., TABLES OF SPECIFIC GRAVITIES, WEIGHTS AND MEASURES, FAHRENHEIT AND CENTIGRADE TEMPERATURES, FRACTIONS AND DECIMAL EQUIVALENTS, POWERS AND ROOTS, AREAS AND CIRCUMFERENCES OF CIRCLES, ETC., ETC.

GENERAL DATA

SHIPPING WEIGHTS OF G. R. S. APPARATUS

Charging Apparatus

	Shipping Weights, Pounds
D. C. Generator, capacity 1.25 K. W. (Page 169),	290
D. C. Generator, capacity 2.50 K. W.,	340
D. C. Generator, capacity 3.25 K. W.,	500
D. C.–D. C. Motor Generator Set, capacity 1.25 K. W. (Page 168),	600
D. C.–D. C. Motor Generator Set, capacity 2.40 K. W.,	800
D. C.–D. C. Motor Generator Set, capacity 3.25 K. W.,	1050

The above weights cover the necessary starting devices and field rheostats.

Transformers

Type K, air cooled (Fig. 249),	20
Type L1, complete with oil, hanger, and cut-outs (Fig. 247),	130
Type L2, complete with oil, hanger, and cut-outs,	175
Type L3, complete with oil, hanger, and cut-outs,	210

Power Switchboards

Board, 24″ x 36″, controlling 1 H. V. battery and 1 generator (Fig. 117),	210
Board, 24″ x 48″, controlling 1 H. V. battery, duplicate sets of L. V. battery and 1 generator (Fig. 119),	410
Board, 48″ x 48″, controlling 1 H. V. battery, duplicate sets of L. V. battery, 4 sets track battery, and 1 generator (Fig. 121),	600

Operating Switchboards

1 Section Board, 12″ x 36″, no voltmeter (Fig. 128),	280
2 Section Board, 24″ x 36″, no voltmeter,	530
3 Section Board, 36″ x 36″, no voltmeter,	800
1 Section Board, 12″ x 48″, with voltmeter,	350
Panel, 12″ x 12″, with voltmeter,	70

Lighting Panels for Power and Operating Boards

Panel, 12″ x 12″, with 5 S. P. S. T. switches (Fig. 130),	90
Panel, 12″ x 18″, with 10 S. P. S. T. switches (Fig. 132),	110
Panel, 12″ x 24″, with 6 D. P. S. T. or 12 S. P. S. T. switches,	150
Panel, 12″ x 36″, with 9 D. P. S. T. or 18 S. P. S. T. switches,	190

Interlocking Machine

Model 2 — 1 tier locking.	
Per lever,	90
Per spare space,	70

	Shipping Weights, Pounds
Model 2 — 2 tier locking.	
Per lever,	100
Per spare space,	80
Model 2 — 3 tier locking (Fig. 137).	
Per lever,	110
Per spare space,	90
Model 2 — 4 tier locking.	
Per lever,	120
Per spare space,	100
Unit Type — 1 tier locking.	
Per lever,	110
Per spare space,	80
Unit Type — 2 tier locking.	
Per lever,	120
Per spare space,	90
Unit Type — 3 tier locking (Fig. 136).	
Per lever,	130
Per spare space,	100
Unit Type — 4 tier locking.	
Per lever,	150
Per spare space,	120

The above weights for machines complete with levers, individual polarized relays, riveted locking, and cabinet.

Complete Set of Locking — Average weights per working lever.	
1 Tier of Locking,	10
2 Tiers of Locking,	15
3 Tiers of Locking,	20
4 Tiers of Locking,	25
Separate Lever complete with polarized relay,	40
Lever Lock (Fig. 141) applied to machine,	10

SWITCH LAYOUTS (Crank Connected)

Single Switch, Model 2 switch machine (Fig. 163),	1000
Single Switch, Model 4 switch machine (Fig. 162),	1500
Split Point Derail, Model 2 switch machine (Fig. 165),	1000
Split Point Derail, Model 4 switch machine (Fig. 164),	1500
Hayes Derail, Model 2 switch machine (Fig. 167),	1100
Hayes Derail, Model 4 switch machine (Fig. 166),	1600
Wharton or Morden Derail, Model 2 switch machine (Fig. 169),	1100
Wharton or Morden Derail, Model 4 switch machine (Fig. 168),	1600
Single Slip Switch (one end), Model 2 switch machine (Fig. 171),	1000
Single Slip Switch (one end), Model 4 switch machine (Fig. 170),	1500
Double Slip Switch (one end), Model 2 switch machine (Fig. 173),	1200

	Shipping Weights, Pounds
Double Slip Switch (one end), Model 4 switch machine (Fig. 172),	1800
Movable Point Frog, Model 2 switch machine (Figs. 175, 177),	1600
Movable Point Frog, Model 4 switch machine (Figs. 174, 176),	2000

The above weights are for switch machines complete with tie plates, throw rod, lock rod, No. 1 switch rod, rail braces, and all necessary bolts, nuts, and cotters. Switch connections insulated. Weights for Model 4 switch machine layouts include switch circuit controller and connections. *Weights do not include detector bars.*

Model 2 Switch Machine (Fig. 159),	500
Model 4 Switch Machine for single switch or derail (Fig. 161),	850
Model 4 Switch Machine for movable point frog or double slip switch (Fig. 160),	950

Detector Bar Layouts (Crank Connected)

1 Bar, same side for Model 2 or Model 4 switch machine,	360
1 Bar, opposite side for Model 2 or Model 4 switch machine,	460
2 Bars, for Model 2 or Model 4 switch machine,	770
1 Bar, for two Model 2 or Model 4 switch machines,	780

The above weights for detector bar layouts are complete with all connections and necessary bolts, nuts, etc. Connections insulated.

Signals — RSA Dimensions

Pipe Bracket Post complete, narrow deck,	3400
Pipe Bracket Post complete, wide deck,	3800
1 Arm Ground Signal complete, 22′ 6″ base to center of arm,	1270
1 Arm Ground Signal complete, 29′ 6″ base to center of arm,	1430
2 Arm Ground Signal complete, 22′ 6″ base to center of lower arm,	1850
2 Arm Ground Signal complete, 28′ 6″ base to center of lower arm,	2000
3 Arm Ground Signal complete, 22′ 6″ base to center of lower arm,	2420
1 Arm Bracket or Bridge Signal complete, 3′ 6″ base to center of arm,	710
1 Arm Bracket or Bridge Signal complete, 10′ 6″ base to center of arm,	900
2 Arm Bracket or Bridge Signal complete, 3′ 6″ base to center of lower arm,	1310

	Shipping Weights, Pounds
2 Arm Bracket or Bridge Signal complete, 9′ 6″ base to center of lower arm,	1450
3 Arm Bracket or Bridge Signal complete, 3′ 6″ base to center of lower arm,	1860

The above signals complete with mechanism, ladders, spectacles, blades, lamp brackets, foundation bolts, etc.

Cantilever Bracket complete,	200
Dummy Mast,	300
Fixed Arm complete,	130
Model 2A, 110 Volt Signal Mechanism complete, with clamp bearing (Fig. 199),	350

Dwarf Signals

Model 2A Dwarf Signal complete (Figs. 204, 205),	380
Model 2, 1 Arm Dwarf Signal complete (Fig. 207),	150
Model 2, 2 Arm Dwarf Signal complete (Fig. 206),	300
Model 3, 1 Arm Dwarf Signal complete (Fig. 208),	140

The above signals complete with spectacle, blade, lamp bracket, foundation bolts, etc.

Switch Circuit Controllers

Model 5, Form A Switch Circuit Controller (Fig. 186),	60
Model 3, Switch Circuit Controller, 4 circuits (Fig. 185),	40
Model 3, Switch Circuit Controller, 8 circuits,	60
Add for Short Operating Rod,	15
Add for Long Operating Rod,	25

Relays and Indicators

Model 9, D. C. Relay, 4-way (Figs. 228, 229),	30
Model 9, D. C. Relay, 8-way,	35
Model 1, D. C. Relay, not inclosed,	30
Model 1, D. C. Relay, inclosed,	35
Model 9, Tower Indicator, 4-way (Fig. 230),	30
Model 9, Tower Indicator, 8-way,	40
Model 9, Indicator Group, with 4-way indicators (Fig. 83), per indicator,	35
Model 9, Indicator, Group with 8-way indicators, per indicator,	45
Model 2, Form A Polyphase Relay, 4-way (Fig. 235),	65
Model 2, Form A Polyphase Relay, 6-way,	70
Model 2, Model 3, or Model Z, Form B Relay, 4-way (Fig. 232),	40
Model 2, Model 3, or Model Z, Form B Relay, 6-way,	45
Model 2, Model 3, or Model Z, Form B Indicating Relay, 4-way (Fig. 234),	50
Model 2, Model 3, or Model Z, Form B Indicating Relay, 6-way,	55

	Shipping Weights, Pounds
Model 2, Model 3, or Model Z, Form B Tower Indicator (Fig. 233),	35

Relay Boxes

1-way Iron Box for D. C. relays,	120
2-way Iron Box for D. C. relays (Fig. 242),	160
3-way Iron Box for D. C. relays,	250
4-way Iron Box for D. C. relays,	225
1-way Wood Box for D. C. relays,	25
2-way Wood Box for D. C. relays (Fig. 243),	35
3-way Wood Box for D. C. relays,	50
1-way Wood Box for Model 2 Form A relays,	40
2-way Wood Box for Model 2 Form A relays (Fig. 241),	55
3-way Wood Box for Model 2 Form A relays,	75

The above boxes complete with terminal board and U bolts or bracket for mounting on stub pole.

Add for mounting on signal mast,	20
Posts for mounting relay box on foundation,	40
Post for mounting relay box on battery chute,	70

Battery Chutes (Page 292)

6-ft. Single Battery Chute, complete with elevator,	260
7-ft. Single Battery Chute, complete with elevator,	290
8-ft. Single Battery Chute, complete with elevator,	350
9-ft. Single Battery Chute, complete with elevator,	390
7-ft. Double Battery Chute, complete with elevator,	520
9-ft. Double Battery Chute, complete with elevator,	650

Impedance Bonds

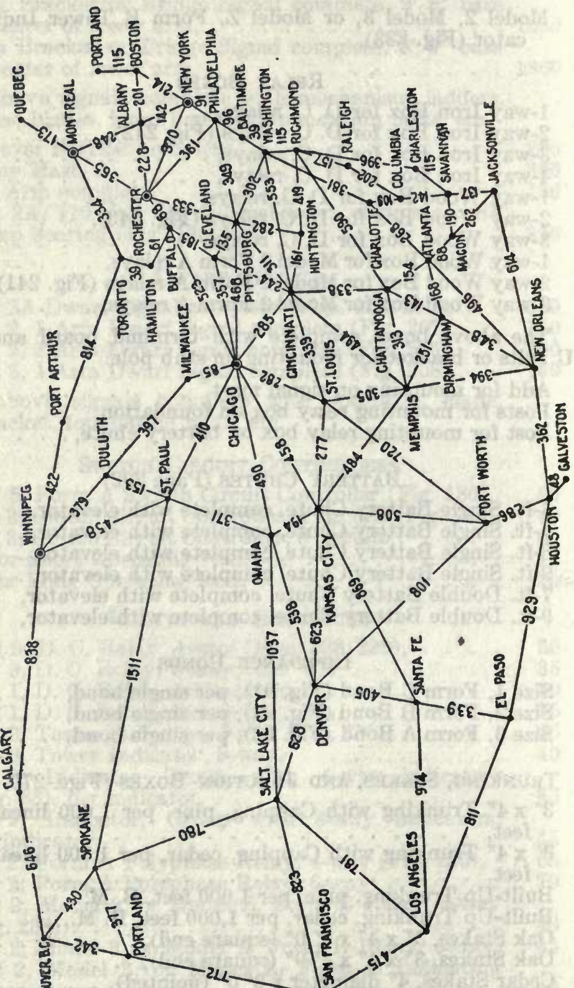
Size 1, Form C Bond (Fig. 91), per single bond,	610
Size 2, Form B Bond (Fig. 92), per single bond,	420
Size 3, Form A Bond (Fig. 92), per single bond,	250

Trunking, Stakes, and Junction Boxes (Figs. 270, 271)

3″ x 4″ Trunking with Capping, pine, per 1,000 lineal feet,	5300
3″ x 4″ Trunking with Capping, cedar, per 1,000 lineal feet,	3000
Built-Up Trunking, pine, per 1,000 feet, B. M.	3350
Built-Up Trunking, cedar, per 1,000 feet, B. M.,	1900
Oak Stakes, 3″ x 4″ x 3′ 0″ (square end),	10
Oak Stakes, 3″ x 4″ x 4′ 0″ (square end),	15
Cedar Stakes, 4″ diameter x 3′ 0″ (pointed),	10
Cedar Stakes, 4″ diameter x 3′ 6″ (pointed),	10
Junction Box, inside dimensions, 15½″ x 15½″ x 11″,	40
Junction Box, inside dimensions, 16″ x 16″ x 20″,	60

SHIPPING DISTANCES BETWEEN THE LARGER CITIES OF THE UNITED STATES AND CANADA

Distances Based on the Shortest Railroad Routes Usually Traveled. G. R. S. Offices Located at Cities Designated by Dot Enclosed within Circle.



COMPLETE LIST OF MAINTENANCE TOOLS REQUIRED AT ELECTRIC INTER-LOCKING PLANTS

Blacksmith Tools

1 Anvil.
1 Forge.
1 Set of tools, including 10 pound hammer, cold cutter and ¾″ punch.

Carpenters Tools

1 18″ square.
1 Jack plane.
1 Brace with set of bits.
1 1³⁄₁₆″ single lip car bit 14″ long.
1 ¾″ wood chisel.
1 26″ No. 9 hand saw.
1 Hand axe.
1 Adze.
1 Claw hammer.

Electrical Tools

1 Soldering furnace-pot and two ladles.
1 Small soldering copper.
2 Screw drivers, 6″ and 10″.
1 Aligator pliers, 8″.
1 Side-cutting pliers, 7″.
1 Contact adjuster.
1 Binding-post wrench.
2 Socket wrenches for ¼″ hexagon nut.
1 Wrench for signal circuit breaker.
1 Crank for switch motor.
1 Hydromotor.
1 Portable volt-ammeter.
1 Solid wrench for ¾″ hexagon nuts.

Line Circuit Tools

1 Belt with safety.
1 Pair 16″ climbers.
1 "Come along" with blocks.
2 Connectors.

Pipe Tools

(For pipe connected detector bars.)

1 Stilson wrench.
2 Pipe rivet punches.
1 Pipe cutter.
1 Stock with 1″ right-hand dies.

Switch Fitting Tools

1 Machinist hammer.
1 Center punch.

2 Cold chisels.
1 12″ tommy bar—bent on both ends.
1 20″ tommy bar—bent on chisel end only.
1 Packer ratchet with 11/16″ and 13/16″ drill.
1 "Old man" for drilling rail.
2 Switch-adjusting wrenches.
3 Two-man "T" socket wrenches for 3/4″ square and hexagon nut, and 3/4″ lag screws.
2 "T" socket wrenches for 5/8″ and 1/2″ lag screws.
4 Solid "S" wrenches for 5/8″ and 3/4″ bolts with square or hexagon nut.
1 Solid wrench for detector bar clips.
1 14″ Monkey wrench.
2 Reamers, 5/8″ and 7/8″.
1 14″ Stilson wrench.
1 6″ Westcott wrench.
4 Files: one-14″ flat bastard, one–10″ flat smooth, one–12″ half-round bastard, one–12″ round.
4 Files: two–6″ rat tail, two saw files.

Track Tools

1 Spike maul.
1 Spike puller.
1 Claw bar.
1 Track wrench.
1 Track shovel.
1 Barn broom.
1 Railroad pick.

Track-Circuit Tools

1 Bonding drill with twelve 9/32″ twist drills.
2 Channel pins punches.
1 Channel pin set (slotted).

Miscellaneous

1 Workbench with combination vise.
1 Drill press with drills.
1 Set taps and dies with stock 1/4″ to 1″.
1 Breast drill with set of drills 1/8″ to 3/8″ by 32nds.
1 Bench emery wheel.
1 Hack saw, 12 blades.
1 Large spout oiler (1 quart).
1 9″ spout oiler (1 pint).
1 6″ spout oiler (1/2 pint).
2 Water pails.
1 Canvas tool bag.

MODEL 1 FORM A LIGHTNING ARRESTER

Fig. 276 illustrates the G. R. S. Co.'s Model 1 Form A lightning arrester, designed for use on signal, telegraph, telephone, crossing alarm circuits, etc.

The arrester has a high efficiency, i. e., a high reactance and negligible ohmic resistance. This high reactance is maintained under all conditions of frequency and current owing to the fact that no iron is used in the core of the reactance coil.

The arrester is small ($1\frac{5}{16}''$ x $4\frac{3}{4}''$ x $4\frac{7}{16}''$) and may be assembled in banks on one inch centers. Connectors between the ground plates are provided, which form a buss bar of ample carrying capacity, thereby making requisite but one ground connection for any number of arresters. Multiple point discharge plates are provided instead of the single point type or one having a circular surface. The parts used in the arrester construction are few, none of them being delicate or easily broken. The connections are all in front, thus allowing it to be easily installed and inspected.

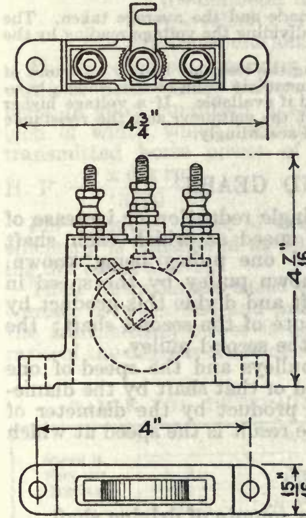


Fig. 276. Model 1 Form A Lightning Arresters

The Model 1 Form A uses the same component parts as the Model 1 arrester, thousands of which are at the present time in service, many of them showing evidence of having taken care of heavy discharges without injury resulting to the arrester or the protected apparatus.

The arresters should be grounded through two No. 8 B. & S. gauge copper wires, insulated above the ground. The wires should be wrapped around and soldered to a galvanized ground rod, not less than one inch in diameter, driven eight feet into the ground.

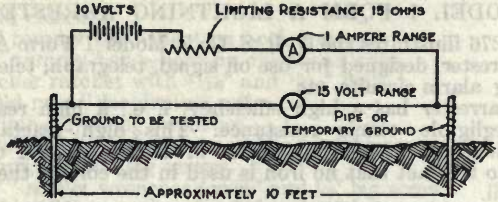


FIG. 277. CIRCUIT FOR TESTING RESISTANCE OF GROUNDS

NOTE.— Several readings should be made and the average taken. The resistance should then be computed by dividing the voltage reading by the current.

The limiting resistance used in making the test may merely be a unit of such resistance as to protect the instruments, it being recommended, however, that a variable resistance be used if available. If a voltage higher than that indicated is used, the range of the voltmeter and the resistance unit employed will have to be increased accordingly.

PULLEYS AND GEARS

When it is desired to secure single reduction or increase of speed by means of belting, the speed at which each shaft should run and the diameter of one pulley being known, multiply the diameter of the known pulley by the speed in revolutions per minute of its shaft and divide this product by the speed in revolutions per minute of the second shaft; the result is the desired diameter of the second pulley.

When the diameter of both pulleys and the speed of one shaft is known, multiply the speed of that shaft by the diameter of its pulley and divide this product by the diameter of the pulley on the other shaft; the result is the speed at which the second shaft will be run.

Let D = diameter of driving pulley.
d = diameter of driven pulley.
S = number of revolutions per minute of driving shaft.
s = number of revolutions per minute of driven shaft.

Then the above may be expressed by the following formula:

$$d = \frac{D \times S}{s}$$

Where a counter-shaft is used, to obtain either size or speed of the main driving or driven pulley, calculate as above, between the known end of the transmission and the counter-shaft and then repeat this calculation between the counter-shaft and the unknown end.

Gears in mesh transmit speeds in proportion to the number of teeth they contain. Count the number of teeth in the gearing and substitute this quantity for the diameter of the pulleys mentioned above, in order to obtain the number of teeth to be cut in unknown gear or speed of the second shaft.

WIDTHS OF BELTING PER HORSE POWER

A rule commonly used for determining the width of belting is that "single" belt will transmit 1 H. P. for each inch in width at a speed of 1,000 feet per minute. If the speed is greater or less the power transmitted is correspondingly increased or decreased.

The rule may be stated as follows:

$$\text{H. P.} = \frac{w \times d \times rpm}{3820} = \frac{w\,v}{1000}$$

In which w = width of belt in inches.
d = diameter of pulley in inches.
v = velocity of belt in feet per minute.
rpm = revolutions per minute.

This is based on a working tension of 30 pounds per inch of width of belt. Many writers give as a safe practice for single belts in good condition a working tension of 45 pounds per inch of width, which formula gives a permissible increase in transmitted horse power of 50 per cent. over the formula $\text{H. P.} = \frac{w \times d \times rpm}{3820}$

For "double" belts of average thickness, the transmitting efficiency is considered as 10 to 7 compared to the single belting discussed above.

These formulas are based on the supposition that the arc of contact between belt and pulley is 180 degrees. For other arcs the transmitting power is approximately proportional to the ratio of the degrees of arc of contact to 180 degrees.

TABLE FOR DETERMINING WIDTH OF BELTING

Speed in Feet per Minute	Width of Belt in Inches				
	2	3	4	5	6
	H. P.	H. P.	H. P.	H. P.	H. P.
500	1	1.5	2	2.5	3
1000	2	3	4	5	6
1500	3	4.5	6	7.5	9
2000	4	6	8	10	12
2500	5	7.5	10	12.5	15
3000	6	9	12	15	18
3500	7	10.5	14	17.5	21
4000	8	12	16	20	24
4500	9	13.5	18	22.5	27
5000	10	15	20	25	30

Note.— Based on the formula $\text{H. P.} = \frac{w \times d \times rpm}{3820} = \frac{wv}{1000}$

In running, the upper side of the belt should sag downward, as the belt will then be in contact with more than half the circumference of the pulley, and the power increased in the proportion referred to in the preceding paragraph. Best results are secured by running belt just tight enough to prevent slipping at normal load.

PAINTING

EXTRACTS FROM R. S. A. SPECIFICATIONS FOR ELECTRIC INTERLOCKING (1910)

800. Paint

Field work.

(*b*) Surfaces covered with rust, grease, dirt, or other foreign substances, shall be thoroughly cleaned before paint or oil is applied.

(*c*) Paint shall not be applied to outside surfaces in freezing weather, nor to wet surfaces, nor until previous coating has thoroughly dried.

(*d*) Finishing coats shall not be applied until after the expiration of forty-eight (48) hours after the previous coating has been applied.

(*e*) Paints mixed on the ground shall be applied within three (3) hours after the pigment and oil are mixed.

(*f*) Priming coats shall be applied as soon as is consistent with the progress of the work.

(*g*) Second coat shall be applied in sufficient time for the third coat to be applied and dry when the installation is completed.

810. Iron Work

(*a*) Iron work (except machine, tie plates, and iron foundation piers) not galvanized shall be painted one (1) coat of red lead and raw linseed oil and two (2) finishing coats.

AMOUNT OF PAINT REQUIRED PER 1000 FEET OF TRUNKING AND CAPPING

Size of Trunking Inches	Size of Capping Inches	Gallons (two coats)
2 x 3	1 x 3	4
3 x 4	1¼ x 4	5½
4 x 7	1½ x 7	9
4 x 10	2 x 10	11

Note.— The covering capacity of paint depends largely on the condition of the surface being finished, the handling of the goods by the painter, and the temperature of the surface painted. The above figures are based on average working conditions.

RAIL SECTIONS

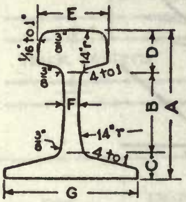


FIG. 278

A. R. A. RAILS—TYPE "A"

Weight per Yard	A	B	C	D	E	F	G
Lbs.	In.	In.	In.	In.	In.	In.	In.
60	4 1/2	2 29/64	13/16	1 15/64	2 1/4	15/32	4
70	4 3/4	2 1/2	29/32	1 11/32	2 3/8	1/2	4 1/4
80	5 1/8	2 23/32	31/32	1 7/16	2 1/2	33/64	4 5/8
90	5 5/8	3 5/32	1	1 15/32	2 9/16	9/16	5 1/8
100	6	3 3/8	1 1/16	1 9/16	2 3/4	9/16	5 1/2

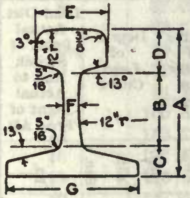


FIG. 279

A. R. A. RAILS—TYPE "B"

Weight per Yard	A	B	C	D	E	F	G
Lbs.	In.	In.	In.	In.	In.	In.	In.
60	4 3/16	2 1/16	7/8	1 1/4	2 1/8	31/64	3 11/16
70	4 35/64	2 17/64	59/64	1 23/64	2 3/8	33/64	4 3/64
80	4 15/16	2 15/32	1	1 15/32	2 7/16	35/64	4 7/16
90	5 17/64	2 5/8	1 1/32	1 39/64	2 9/16	9/16	4 49/64
100	5 41/64	2 55/64	1 5/64	1 45/64	2 21/32	9/16	5 9/64

A. S. C. E. RAILS

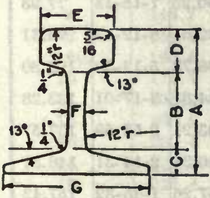


FIG. 280

Weight per Yard	A	B	C	D	E	F	G
Lbs.	In.	In.	In.	In.	In.	In.	In.
55	4 1/16	2 11/64	23/32	1 11/64	2 1/4	15/32	4 1/16
60	4 1/4	2 17/64	49/64	1 7/32	2 3/8	31/64	4 1/4
65	4 7/16	2 3/8	25/32	1 9/32	2 13/32	1/2	4 7/16
70	4 5/8	2 15/32	13/16	1 11/32	2 7/16	33/64	4 5/8
75	4 13/16	2 35/64	27/32	1 27/64	2 15/32	17/32	4 13/16
80	5	2 5/8	7/8	1 1/2	2 1/2	35/64	5
85	5 3/16	2 3/4	57/64	1 35/64	2 9/16	9/16	5 3/16
90	5 3/8	2 55/64	59/64	1 19/32	2 5/8	9/16	5 3/8
95	5 9/16	2 63/64	15/16	1 41/64	2 11/16	9/16	5 9/16
100	5 3/4	3 5/64	31/32	1 45/64	2 3/4	9/16	5 3/4
110	6 1/8	3 11/32	1	1 25/32	2 7/8	37/64	6 1/8

TABLE OF TURNOUTS FROM STRAIGHT TRACK

GAUGE, 4 FEET, 8½ INCHES. THROW OF SWITCH, 5 INCHES

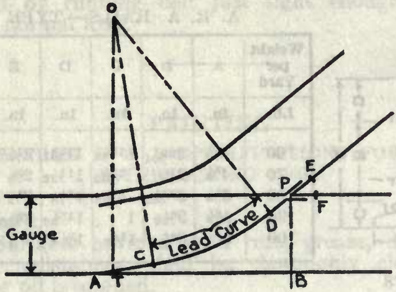


FIG. 281

Frog Number	Frog Angle FPE (Deg. Min. Sec.)	Length Point of Frog to Toe PD (Ft. In.)	Length Point of Frog to Heel PE (Ft. In.)	Length of Switch Rail AC (Ft. In.)	Switch Angle BAC = TOC (Deg. Min. Sec.)	Radius of Center Line OC−½ ga (Ft.)	Degree of Lead Curve (Deg Min. Sec.)	Lead-Dist. Actual Point of Switch Rail to Actual Point of Frog AB (Ft.)
6	9-31-38	4– 0	7– 0	11–0	2-36-19	265.39	21-43-04	47.98
7	8-10-16	4– 5	8– 1	16–6	1-44-11	362.08	15-52-29	62.10
8	7-09-10	4– 9	8– 9	16–6	1-44-11	487.48	11-46-27	67.98
9	6-21-35	6– 0	10– 0	16–6	1-44-11	605.18	9-28-42	72.28
9½	6-01-32	6– 0	10– 0	16–6	1-44-11	695.45	8-14-45	75.71
10	5-43-29	6– 0	10– 6	16–6	1-44-11	790.25	7-15-18	77.93
11	5-12-18	6– 0	11– 6	22–0	1-18- 8	922.65	6-12-47	94.31
12	4-46-19	6– 5	12– 1	22–0	1-18- 8	1098.73	5-12-59	100.80
15	3-49-06	7– 8	14–10	33–0	0-52- 5	1744.38	3-17-01	133.28
16	3-34-47	8– 0	16– 0	33–0	0-52- 5	1993.24	2-52-59	137.57
18	3-10-56	8–10	17– 8	33–0	0-52- 5	2546.31	2-14-31	146.51
20	2-51-51	9– 8	19– 4	33–0	0-52- 5	3257.26	1-45-32	157.42
24	2-23-13	11– 4	23– 2	33–0	0-52- 5	4886.16	1-10-21	177.22

Above from table by American Railway Engineering Association.

TABLE OF CROSSOVERS

GAUGE, 4 FEET, 8½ INCHES. THROW OF SWITCH, 5 INCHES

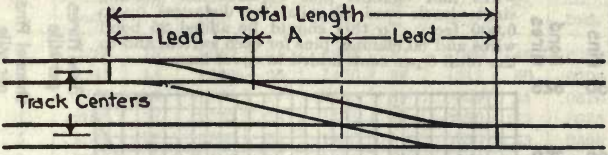


FIG. 282

Frog Number	Lead	Distance (A) between Frog Points for Track Centers Below					
		11′	12′	13′	14′	15′	16′
	Feet	Feet	Feet	Feet	Feet	Feet	Feet
6	47.98	9.5	15.5	21.5	27.5	33.5	39.5
7	62.10	11.1	18.1	25.1	32.1	39.1	46.1
8	67.98	12.7	20.7	28.7	36.7	44.7	52.7
9	72.28	14.2	23.2	32.2	41.2	50.2	59.2
9½	75.71	15.0	24.5	34.0	43.5	53.0	62.5
10	77.93	15.8	25.8	35.8	45.8	55.8	65.8
11	94.31	17.4	28.4	39.4	50.4	61.4	72.4
12	100.80	19.0	31.0	43.0	55.0	67.0	79.0
15	133.28	23.8	38.8	53.8	68.8	83.8	98.8
16	137.57	25.3	41.3	57.3	73.3	89.3	105.3
18	146.51	28.4	46.4	64.4	82.4	100.4	118.4
20	157.42	31.6	51.6	71.6	91.6	111.6	131.6
24	177.22	38.0	62.0	86.0	110.0	134.0	158.0

Frog Number	Total Length of Crossover for Track Centers Below					
	11′	12′	13′	14′	15′	16′
	Feet	Feet	Feet	Feet	Feet	Feet
6	105.5	111.5	117.5	123.5	129.5	135.5
7	135.3	142.3	149.3	156.3	163.3	170.3
8	148.7	156.7	164.7	172.7	180.7	188.7
9	158.8	167.8	176.8	185.8	194.8	203.8
9½	166.4	175.9	185.4	194.9	204.4	213.9
10	171.7	181.7	191.7	201.7	211.7	221.7
11	206.0	217.0	228.0	239.0	250.0	261.0
12	220.6	232.6	244.6	256.6	268.6	280.6
15	290.4	305.4	320.4	335.4	350.4	365.4
16	300.4	316.4	332.4	348.4	364.4	380.4
18	321.4	339.4	357.4	375.4	393.4	411.4
20	346.4	366.4	386.4	406.4	426.4	446.4
24	392.4	416.4	440.4	464.4	488.4	512.4

NOTE.—Distance (A) between frog points based on formula:
Distance = (track centers − 2 x gauge) x frog number.

BOND WIRES AND CHANNEL PINS

Diagram below gives the actual number of bond wires and channel pins required for bonding single track road (2 rails) for distances up to 6,000 feet. To this should be added 25 bond wires and 50 channel pins for each switch, and to the total 5 per cent. added to cover loss.

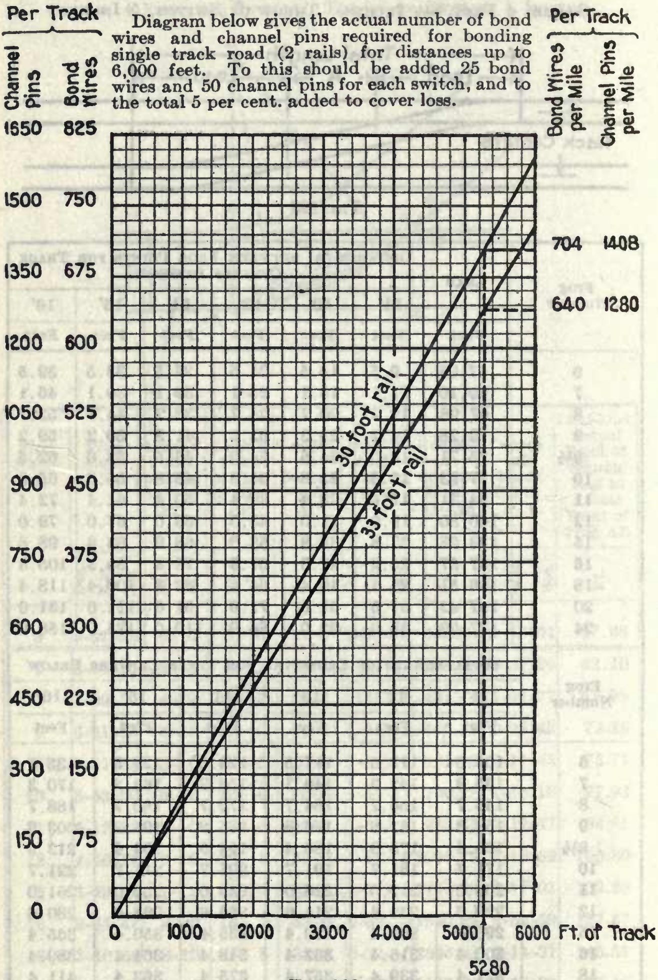


Fig. 283

TWIST DRILL AND STEEL WIRE GAUGE

No.	Size Inch	No.	Size Inch	No.	Size Inch	No.	Size Inch	No.	Size Inch
1	.2280	13	.1850	25	.1495	37	.1040	49	.0730
2	.2210	14	.1820	26	.1470	38	.1015	50	.0700
3	.2130	15	.1800	27	.1440	39	.0995	51	.0670
4	.2090	16	.1770	28	.1405	40	.0980	52	.0635
5	.2055	17	.1730	29	.1360	41	.0960	53	.0595
6	.2040	18	.1695	30	.1285	42	.0935	54	.0550
7	.2010	19	.1660	31	.1200	43	.0890	55	.0520
8	.1990	20	.1610	32	.1160	44	.0860	56	.0465
9	.1960	21	.1590	33	.1130	45	.0820	57	.0430
10	.1935	22	.1570	34	.1110	46	.0810	58	.0420
11	.1910	23	.1540	35	.1100	47	.0785	59	.0410
12	.1890	24	,1520	36	.1065	48	.0760	60	.0400

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STUBS' STEEL WIRE GAUGE

No.	Size Inch	No.	Size Inch	No.	Size Inch	No.	Size Inch	No.	Size Inch
Z	.413	D	.246	19	.164	41	.095	63	.036
Y	.404	C	.242	20	.161	42	.092	64	.035
X	.397	B	.238	21	.157	43	.088	65	.033
W	.386	A	.234	22	.155	44	.085	66	.032
V	.377	1	.227	23	.153	45	.081	67	.031
U	.368	2	.219	24	.151	46	.079	68	.030
T	.358	3	.212	25	.148	47	.077	69	.029
S	.348	4	.207	26	.146	48	.075	70	.027
R	.339	5	.204	27	.143	49	.072	71	.026
Q	.332	6	.201	28	.139	50	.069	72	.024
P	.323	7	.199	29	.134	51	.066	73	.023
O	.316	8	.197	30	.127	52	.063	74	.022
N	.302	9	.194	31	.120	53	.058	75	.020
M	.295	10	.191	32	.115	54	.055	76	.018
L	.290	11	.188	33	.112	55	.050	77	.016
K	.281	12	.185	34	.110	56	.045	78	.015
J	.277	13	.182	35	.108	57	.042	79	.014
I	.272	14	.180	36	.106	58	.041	80	.013
H	.266	15	.178	37	.103	59	.040	...	....
G	.261	16	.175	38	.101	60	.039	...	....
F	.257	17	.172	39	.099	61	.038	...	....
E	.250	18	.168	40	.097	62	.037	...	....

The Stubs' Steel Wire Gauge is used in measuring drawn steel wire or drill rods of Stubs' make, and is also used by many makers of American drill rods.

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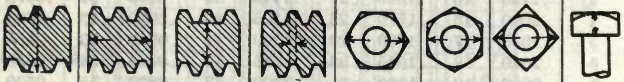
STANDARD SCREW THREADS, NUTS, BOLT AND LAG HEADS
U. S. STANDARD



Diam. of Screw Inch	Threads per Inch	Diam. of Core Inch	Width of Flat Inch	Outside Diam. Hex. Head Inch	Inside Diam. Hex. or Sq. Head Inch	Diagonal Sq. Head Inch	Height of Head Inch
1/4	20	.185	.0062	9/16	1/2	11/16	1/4
5/16	18	.240	.0070	11/16	19/32	13/16	19/64
3/8	16	.294	.0078	25/32	11/16	31/32	11/32
7/16	14	.344	.0089	43/48	25/32	1 1/16	25/64
1/2	13	.400	.0096	1	7/8	1 1/4	7/16
9/16	12	.454	.0104	1 7/64	31/32	1 5/16	31/64
5/8	11	.507	.0113	1 7/32	1 1/16	1 1/2	17/32
3/4	10	.620	.0125	1 7/16	1 1/4	1 3/4	5/8
7/8	9	.731	.0140	1 21/32	1 7/16	2 1/32	23/32
1	8	.837	.0156	1 7/8	1 5/8	2 5/16	13/16
1 1/8	7	.940	.0180	2 3/32	1 13/16	2 1/2	29/32
1 1/4	7	1.065	.0180	2 5/16	2	2 27/32	1
1 3/8	6	1.160	.0210	2 1/2	2 3/16	3 1/16	1 3/32
1 1/2	6	1.284	.0210	2 3/4	2 3/8	3 3/8	1 3/16
1 5/8	5 1/2	1.389	.0227	2 15/16	2 9/16	3 5/8	1 9/32
1 3/4	5	1.490	.0250	3 3/16	2 3/4	3 29/32	1 3/8
1 7/8	5	1.615	.0250	3 13/32	2 15/16	4 3/16	1 15/32
2	4 1/2	1.712	.0280	3 5/8	3 1/8	4 7/16	1 9/16
2 1/4	4 1/2	1.962	.0280	4 1/16	3 1/2	4 31/32	1 3/4
2 1/2	4	2.175	.0310	4 1/2	3 7/8	5 1/2	1 15/16
2 3/4	4	2.425	.0310	4 29/32	4 1/4	6	2 1/8
3	3 1/2	2.628	.0357	5 3/8	4 5/8	6 9/16	2 5/16
3 1/4	3 1/2	2.878	.0357	5 3/4	5	7 1/8	2 1/2
3 1/2	3 1/4	3.100	.0384	6 7/64	5 3/8	7 5/8	2 11/16
3 3/4	3	3.317	.0410	6 5/8	5 3/4	8 3/16	2 7/8
4	3	3.566	.0410	7 3/64	6 1/8	8 11/16	3 1/16
4 1/4	2 7/8	3.798	.0435	7 1/2	6 1/2	9 1/4	3 1/4
4 1/2	2 3/4	4.027	.0460	7 31/32	6 7/8	9 3/4	3 7/16
4 3/4	2 5/8	4.255	.0480	8 3/8	7 1/4	10 9/32	3 5/8
5	2 1/2	4.480	.0500	8 13/16	7 5/8	10 13/16	3 13/16
5 1/4	2 1/2	4.730	.0500	9 1/4	8	11 3/8	4
5 1/2	2 3/8	4.953	.0526	9 11/16	8 3/8	11 29/32	4 3/16
5 3/4	2 3/8	5.203	.0526	10 1/8	8 3/4	12 7/16	4 3/8
6	2 1/4	5.423	.0555	10 9/16	9 1/8	12 9/16	4 9/16

NOTE.—Threads have an angle of 60 degrees, with flat tops and bottoms.

STANDARD MACHINE SCREWS

No.	Threads per Inch	Diam. of Body	Diam. of Flat Head	Diam. of Round Head	Diam. of Filister Head	Lengths From	Lengths To	Clearance Drill
		Inch	Inch	Inch	Inch	Inch	Inch	
2	56	.0842	.1631	.1544	.1332	3/16	1/2	41–43
4	32, 36, 40	.1105	.2158	.2028	.1747	3/16	3/4	30–32
6	30, 32	.1368	.2684	.2512	.2175	3/16	1	27–28
8	30, 32	.1631	.3210	.2936	.2610	1/4	1 1/4	17–18
10	24, 30, 32	.1894	.3737	.3480	.3035	1/4	1 1/2	11– 8
12	20, 24	.2158	.4263	.3922	.3445	3/8	1 3/4	2– 1
14	20, 24	.2421	.4790	.4364	.3885	3/8	2	1/4

Note.—Lengths vary by 16ths from 3/16 to 1/2, by 8ths from 1/2 to 1 1/2, by 4ths from 1 1/2 to 2.

STANDARD DIMENSIONS OF WROUGHT-IRON WELDED PIPE BRIGGS' STANDARD

Nominal Inside Diam.	Actual Outside Diam.	Thickness of Metal	Length of Pipe per Sq. Ft. Outside Surface	Internal Area	Weight of Pipe per Lineal Foot	Number of Threads per Inch
Ins.	Ins.	Ins.	Ft.	Sq. In.	Lbs.	No.
1/4	.540	.088	7.075	.104	.42	18
3/8	.675	.091	5.658	.191	.56	18
1/2	.840	.109	4.547	.304	.84	14
3/4	1.050	.113	3.638	.533	1.12	14
1	1.315	.134	2.904	.861	1.67	11 1/2
1 1/4	1.660	.140	2.301	1.496	2.24	11 1/2
1 1/2	1.900	.145	2.010	2.036	2.68	11 1/2
2	2.375	.154	1.608	3.356	3.61	11 1/2
2 1/2	2.875	.204	1.329	4.780	5.74	8
3	3.500	.217	1.091	7.383	7.54	8
3 1/2	4.000	.226	.955	9.887	9.00	8
4	4.500	.237	.849	12.730	10.66	8
4 1/2	5.000	.246	.764	15.961	12.34	8
5	5.563	.259	.687	19.986	14.50	8
6	6.625	.280	.577	28.890	18.76	8
7	7.625	.301	.501	38.738	23.27	8
8	8.625	.322	.443	50.027	28.18	8
9	9.625	.344	.397	62.730	33.70	8
10	10.75	.366	.355	78.823	40.06	8

SQUARE HEAD LAG SCREWS

Diameter in Inches	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1
Length in Inches	Average Weight per Hundred								
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1½	4.2	6.5	9.2	13.0	....	....	....	....	....
1¾	4.7	7.1	10.0	13.8	....	....	....	....	....
2	5.2	7.7	10.9	14.9	23.0	24.8	....	....	....
2¼	5.7	8.4	11.8	16.1	24.5	27.3	....	....	....
2½	6.2	9.2	12.7	17.4	26.0	29.0	43.0	....	....
3	7.2	10.6	14.6	19.0	29.2	32.9	48.3	75.0	....
3½	8.2	12.0	16.6	21.5	32.5	36.9	53.8	78.5	90
4	9.2	13.5	18.8	24.0	35.9	41.0	59.6	82.0	99
4½	10.2	15.0	20.7	26.5	39.3	44.9	65.5	86.0	108
5	11.3	16.5	22.8	29.0	42.7	48.8	71.5	90.0	118
5½	12.4	18.0	24.9	31.5	46.1	52.7	77.5	98.0	128
6	13.5	19.5	27.0	34.0	49.5	56.6	83.5	106.0	138

NOTE.—For dimensions of lag screw heads, see page 380.

COMMON WIRE NAILS

Size	Length in Inches	Diameter in Inches	Approx. Number to Lb.	Approx. Lbs. per 1000
2D	1	.072	876	1.14
3D	1¼	.080	568	1.76
4D	1½	.100	316	3.16
5D	1¾	.100	271	3.69
6D	2	.113	181	5.53
7D	2¼	.113	161	6.21
8D	2½	.131	106	9.43
9D	2¾	.131	96	10.4
10D	3	.148	69	14.5
12D	3¼	.148	63	15.9
16D	3½	.162	49	20.4
20D	4	.192	31	32.3
30D	4½	.207	24	41.7
40D	5	.225	18	55.6
50D	5½	.244	14	71.4
60D	6	.263	11	90.9

TABLE OF BOARD MEASURE

Size	Length in Feet				
	10	12	14	16	18
	Feet Board Measure				
1 x 2	1⅔	2	2⅓	2⅔	3
1 x 4	3⅓	4	4⅔	5⅓	6
1 x 6	5	6	7	8	9
1 x 8	6⅔	8	9⅓	10⅔	12
1 x 10	8⅓	10	11⅔	13⅓	15
1 x 12	10	12	14	16	18
1 x 14	11⅔	14	16⅓	18⅔	21
2 x 4	6⅔	8	9⅓	10⅔	12
2 x 6	10	12	14	16	18
2 x 8	13⅓	16	18⅔	21⅓	24
2 x 10	16⅔	20	23⅓	26⅔	30
2 x 12	20	24	28	32	36
2 x 14	23⅓	28	32⅔	37⅓	42
3 x 8	20	24	28	32	36
3 x 10	25	30	35	40	45
3 x 12	30	36	42	48	54
3 x 14	35	42	49	56	63
4 x 4	13⅓	16	18⅔	21⅓	24
4 x 6	20	24	28	32	36
4 x 8	26⅔	32	37⅓	42⅔	48
4 x 10	33⅓	40	46⅔	53⅓	60
4 x 12	40	48	56	64	72
4 x 14	46⅔	56	65⅓	74⅔	84

NOTE.—Length in feet × width in feet × thickness in inches = number of feet board measure. (1 cu. ft. of lumber = 12 board feet.)

BAUMÉ'S HYDROMETER AND SPECIFIC GRAVITIES COMPARED

Degrees Baumé	Liquids Heavier than Water, Sp. Gr.	Liquids Lighter than Water, Sp. Gr.	Degrees Baumé	Liquids Heavier than Water, Sp. Gr.	Liquids Lighter than Water, Sp. Gr.
0.0	1.000	.....	28.0	1.239	0.886
1.0	1.007	.....	29.0	1.250	0.881
2.0	1.014	.....	30.0	1.261	0.875
3.0	1.021	.....	31.0	1.272	0.870
4.0	1.028	.....	32.0	1.283	0.864
5.0	1.036	.....	33.0	1.295	0.859
6.0	1.043	.....	34.0	1.306	0.854
7.0	1.051	.....	35.0	1.318	0.849
8.0	1.058	.....	36.0	1.330	0.843
9.0	1.066	.....	37.0	1.343	0.838
10.0	1.074	1.000	38.0	1.355	0.833
11.0	1.082	0.993	39.0	1.368	0.828
12.0	1.090	0.986	40.0	1.381	0.824
13.0	1.099	0.979	41.0	1.394	0.819
14.0	1.107	0.972	42.0	1.408	0.814
15.0	1.115	0.966	44.0	1.436	0.805
16.0	1.124	0.959	46.0	1.465	0.796
17.0	1.133	0.952	48.0	1.495	0.787
18.0	1.142	0.946	50.0	1.526	0.778
19.0	1.151	0.940	52.0	1.559	0.769
20.0	1.160	0.933	54.0	1.593	0.761
21.0	1.169	0.927	56.0	1.629	0.753
22.0	1.179	0.921	58.0	1.667	0.745
23.0	1.189	0.915	60.0	1.706	0.737
24.0	1.198	0.909	65.0	1.813	0.718
25.0	1.208	0.903	70.0	1.933	0.700
26.0	1.219	0.897	75.0	2.071	0.683
27.0	1.229	0.892			

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SPECIFIC GRAVITY OF LIQUIDS AT 60 DEGREES FAHR.

Acid, Muriatic, ...	1.200	Oil, Olive, ...	0.92
Acid, Nitric, ...	1.217	Oil, Palm, ...	0.97
Acid, Sulphuric, ...	1.849	Oil, Petroleum, . . .	0.78 to 0.88
Alcohol, pure, ...	0.794	Oil, Rape, ...	0.92
Alcohol, 95 per cent., . .	0.816	Oil, Turpentine, . . .	0.87
Alcohol, 50 per cent., . .	0.934	Oil, Whale, ...	0.92
Ammonia, 27.9 per cent., .	0.891	Tar, ...	1.
Bromide, ...	2.97	Vinegar, ...	1.08
Carbon, disulphide, . . .	1.26	Water, ...	1.
Ether, Sulphuric, ...	0.72	Water, Sea, ...	1.026 to 1.03
Oil, Linseed, ...	0.94		

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SPECIFIC GRAVITY AND WEIGHT OF WOOD

	Specific Gravity	Avge.	Weight per Cubic Foot, Pounds		Specific Gravity	Avge.	Weight per Cubic Foot, Pounds
Alder, ...	0.56 to 0.80	0.68	42	Hornbeam,	0.76	0.76	47
Apple, . . .	0.73 to 0.79	0.76	47	Juniper, . .	0.56	0.56	35
Ash, ...	0.60 to 0.84	0.72	45	Larch, . . .	0.56	0.56	35
Bamboo, . .	0.31 to 0.40	0.35	22	Lignum vitæ	0.65 to 1.33	1.00	62
Beech, . . .	0.62 to 0.85	0.73	46	Linden, . .	0.604		37
Birch, ...	0.56 to 0.74	0.65	41	Locust, . .	0.728		46
Box, ...	0.91 to 1.33	1.12	70	Mahogany, .	0.56 to 1.06	0.81	51
Cedar, ...	0.49 to 0.75	0.62	39	Maple, . . .	0.57 to 0.79	0.68	42
Cherry, . . .	0.61 to 0.72	0.66	41	Mulberry, .	0.56 to 0.90	0.73	46
Chestnut, . .	0.46 to 0.66	0.56	35	Oak, Live, .	0.96 to 1.26	1.11	69
Cork, ...	0.24	0.24	15	Oak, White,	0.69 to 0.86	0.77	48
Cypress, . . .	0.41 to 0.66	0.53	33	Oak, Red, .	0.73 to 0.75	0.74	46
Dogwood, . .	0.76	0.76	47	Pine, White,	0.35 to 0.55	0.45	28
Ebony, . . .	1.13 to 1.33	1.23	76	Pine, Yellow,	0.46 to 0.76	0.61	38
Elm, ...	0.55 to 0.78	0.61	38	Poplar, . .	0.38 to 0.58	0.48	30
Fir, ...	0.48 to 0.70	0.59	37	Spruce, . .	0.40 to 0.50	0.45	28
Gum, ...	0.84 to 1.00	0.92	57	Sycamore, .	0.59 to 0.62	0.60	37
Hackmatack, .	0.59	0.59	37	Teak, . . .	0.66 to 0.98	0.82	51
Hemlock, . .	0.36 to 0.41	0.38	24	Walnut, . .	0.50 to 0.67	0.58	36
Hickory, . . .	0.69 to 0.94	0.77	48	Willow, . .	0.49 to 0.59	0.54	34
Holly, ...	0.76	0.76	47				

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SPECIFIC GRAVITY AND WEIGHT OF STONES, BRICK, CEMENT, ETC. (Pure Water=1.00.)

	Sp. Gr.	Lb. per Cu. Ft.
Asphaltum,	1.39	87
Brick, Soft,	1.6	100
Brick, Common,	1.79	112
Brick, Hard,	2.0	125
Brick, Pressed,	2.16	135
Brick, Fire,	2.24 to 2.4	140 to 150
Brick, Sand-lime,	2.18	136
Brickwork in mortar,	1.6	100
Brickwork in cement,	1.79	112
Cement, American, natural,	2.8 to 3.2	...
Cement, Portland,	3.05 to 3.15	...
Cement, Portland, loose,	....	92
Cement, Portland, in barrels,	....	115
Clay,	1.92 to 2.4	120 to 150
Concrete,	1.92 to 2.48	120 to 155
Earth, loose,	1.15 to 1.28	72 to 80
Earth, rammed,	1.44 to 1.76	90 to 110
Emery,	4.	250
Glass,	2.5 to 2.75	156 to 172
Glass, flint,	2.88 to 3.14	180 to 196
Gneiss } Granite }	2.56 to 2.72	160 to 170
Gravel,	1.6 to 1.92	100 to 120
Gypsum,	2.08 to 2.4	130 to 150
Hornblende,	3.2 to 3.52	200 to 220
Ice,	0.88 to 0.92	55 to 57
Lime, quick, in bulk,	0.8 to 0.96	50 to 60
Limestone,	2.30 to 2.90	140 to 185
Magnesia, Carbonate,	2.4	150
Marble,	2.56 to 2.88	160 to 180
Masonry, dry rubble,	2.24 to 2.56	140 to 160
Masonry, dressed,	2.24 to 2.88	140 to 180
Mica,	2.80	175
Mortar,	1.44 to 1.6	90 to 100
Mud, soft flowing,	1.67 to 1.92	104 to 120
Pitch,	1.15	72
Plaster of Paris,	1.50 to 1.81	93 to 113
Quartz,	2.64	165
Sand,	1.44 to 1.76	90 to 110
Sand, wet,	1.89 to 2.07	118 to 129
Sandstone,	2.24 to 2.4	140 to 150
Slate,	2.72 to 2.88	170 to 180
Soapstone,	2.65 to 2.8	166 to 175
Stone, various,	2.16 to 3.4	135 to 200
Trap,	2.72 to 3.4	170 to 200
Tile,	1.76 to 1.92	110 to 120

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SPECIFIC GRAVITY AND WEIGHT OF METALS

	Specific Gravity. Range According to Several Authorities	Specific Gravity. Approx. Mean Value, used in Calculation of Weight	Weight per Cubic Foot Lbs.	Weight per Cubic Inch Lbs.
Aluminum, ...	2.56 to 2.71	2.67	166.5	0.0963
Antimony, ...	6.66 to 6.86	6.76	421.6	0.2439
Bismuth, ...	9.74 to 9.90	9.82	612.4	0.3544
Brass: Copper+Zinc				
80 20	7.8 to 8.6	8.60	536.3	0.3103
70 30		8.40	523.8	0.3031
60 40		8.36	521.3	0.3017
50 50		8.20	511.4	0.2959
Bronze { Cop., 95 to 80; Tin, 5 to 20 }	8.52 to 8.96	8.853	552.	0.3195
Cadmium, ...	8.6 to 8.7	8.65	539.	0.3121
Calcium, ...	1.58	1.58	98.5	0.0570
Chromium, ...	5.0	5.0	311.8	0.1804
Cobalt, ...	8.5 to 8.6	8.55	533.1	0.3085
Gold, pure, ...	19.245 to 19.361	19.258	1200.9	0.6949
Copper, ...	8.69 to 8.92	8.853	552.	0.3195
Iridium, ...	22.38 to 23.	22.38	1396.	0.8076
Iron, Cast, ...	6.85 to 7.48	7.218	450.	0.2604
Iron, Wrought, . . .	7.4 to 7.9	7.70	480.	0.2779
Lead, ...	11.07 to 11.44	11.38	709.7	0.4106
Manganese, ...	7. to 8.	8.	499.	0.2887
Magnesium, ...	1.69 to 1.75	1.75	109.	0.0641
Mercury, . . . { 32°	13.60 to 13.62	13.62	849.3	0.4915
60°	13.58	13.58	846.8	0.4900
212° }	13.37 to 13.38	13.38	834.4	0.4828
Nickel, ...	8.279 to 8.93	8.8	548.7	0.3175
Platinum, ...	20.33 to 22.07	21.5	1347.0	0.7758
Potassium, ...	0.865	0.865	53.9	0.0312
Silver, ...	10.474 to 10.511	10.505	655.1	0.3791
Sodium, ...	0.97	0.97	60.5	0.0350
Steel, ...	7.69* to 7.932†	7.854	489.6	0.2834
Tin, ...	7.291 to 7.409	7.350	458.3	0.2652
Titanium, ...	5.3	5.3	330.5	0.1913
Tungsten, ...	17. to 17.6	17.3	1078.7	0.6243
Zinc, ...	6.86 to 7.20	7.00	436.5	0.2526

* Hard and burned.

† Very pure and soft. The sp. gr. decreases as the carbon is increased.

In the first column of figures the lowest are usually those of cast metals, which are more or less porous; the highest are of metals finely rolled or drawn into wire.

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TABLES OF WEIGHTS AND MEASURES

Linear Measure

12	inches (in.), ...	=1 foot (ft.)
3	feet, ...	=1 yard (yd.)
5.5	yards, ...	=1 rod (rd.)
40	rods, ...	=1 furlong (fur.)
8	furlongs, ...	=1 mile (mi.)

1 mi. = 8 fur. = 320 rods = 1760 yd. = 5280 ft. = 63,360 in.

Square Measure

144	square inches (sq. in.),	=1 square foot (sq. ft.)
9	square feet, ...	=1 square yard (sq. yd.)
30¼	square yards, ...	=1 square rod (sq. rd.)
160	square rods, ...	=1 acre (A)
640	acres, ...	=1 square mile (sq. mi.)

1 sq. mi. = 640 acres = 102,400 sq. rd. = 3,097,600 sq. yd. = 27,878,400 sq. ft. = 4,014,489,600 sq. in.

Cubic Measure

1,728	cubic inches (cu. in.),	=1 cubic foot (cu. ft.)
27	cubic feet, ...	=1 cubic yard (cu. yd.)
128	cubic feet, ...	=1 cord (cd.)
24¾	cubic feet, ...	=1 perch (P.)

1 cu. yd. = 27 cu. ft. = 46,656 cu. in.

Measures of Angles or Arcs

60	seconds (″), ...	=1 minute (′)
60	minutes, ...	=1 degree (°)
90	degrees, ...	=1 right angle or quadrant (□)
360	degrees, ...	=1 circle (cir.)

1 cir. = 360° = 21,600′ = 1,296,000″.

Avoirdupois Weight

437.5	grains (gr.), ...	=1 ounce (oz.)
16	ounces, ...	=1 pound (lb.)
100	pounds, ...	=1 hundredweight (cwt.)
20	cwt. or 2,000 lb., . .	=1 ton (T.)

1 T. = 20 cwt. = 2,000 lb. = 32,000 oz. = 14,000,000 gr.
The avoirdupois pound contains 7,000 grains.

Dry Measure

2	pints (pt.), ...	=1 quart (qt.)
8	quarts, ...	=1 peck (pk.)
4	pecks, ...	=1 bushel (bu.)

1 bu. = 4 pk. = 32 qt. = 64 pt.

The U. S. struck bushel contains 2,150.42 cubic inches = 1.2444 cubic feet. By law, its dimensions are those of a cylinder 18½ inches in diameter and 8 inches deep. The heaped bushel is equal to 1¼ struck bushels, the cone being six inches high. The dry gallon contains 268.8 cubic inches, being ⅛ of a struck bushel.

For approximations, the bushel may be taken at 1¼ cubic feet, or a cubic foot may be considered ⅘ of a bushel.

The British bushel contains 2,218.19 cubic inches = 1.2837 cubic feet = 1.032 U. S. bushels.

Liquid Measure

4	gills (gi.),	. . . . .	= 1 pint (pt.)
2	pints,	. . . .	= 1 quart (qt.)
4	quarts,	. . . . . .	= 1 gallon (gal.)
31½	gallons,	. . . . . .	= 1 barrel (bbl.)
2	barrels,	. . . . . .	= 1 hogshead (hhd.)

1 hhd. = 2 bbl. = 63 gal. = 252 qt. = 504 pt. = 2,016 gi.

The U. S. gallon contains 231 cubic inches = .134 cubic feet approximate; or 1 cubic foot contains 7.481 gallons. The following cylinders contain the given measures very closely:

	Diam.	Height		Diam.	Height
Gill, ...	1¾ in.	3 in.	Gallon, . .	7 in.	6 in.
Pint, ...	3½ in.	3 in.	8 gallons, .	14 in.	12 in.
Quart, ...	3½ in.	6 in.	10 gallons, .	14 in.	15 in.

When water is at its maximum density, 1 cubic foot weighs 62.425 pounds and 1 gallon weighs 8.345 pounds.

For approximations, 1 cubic foot of water is considered equal to 7½ gallons and 1 gallon as weighing 8⅓ pounds.

The British Imperial gallon, both liquid and dry, contains 277.274 cubic inches = .16046 cubic feet, and is equivalent to the volume of 10 pounds of pure water at 62 degrees Fahr. To reduce British to U. S. liquid gallons, multiply by 1.2. Conversely, to convert U. S. into British liquid gallons, divide by 1.2; or, increase the number of gallons ⅕.

Miscellaneous Table

12 articles, ...	= 1 dozen.
12 dozen, ...	= 1 gross.
12 gross, ...	= 1 great gross.
2 articles, ...	= 1 pair.
20 articles, ...	= 1 score.
24 sheets, ...	= 1 quire.
20 quires, ...	= 1 ream.

FRENCH OR METRIC MEASURE

The metric unit of length is the metre = 39.37 inches.

The metric unit of weight is the gram = 15.432 grains.

The following prefixes are used for subdivisions and multiples: Milli = 1/1000, Centi = 1/100, Deci = 1/10, Deca = 10, Hecto = 100, Kilo = 1000, Myria = 10,000.

FRENCH EQUIVALENTS OF AMERICAN AND BRITISH MEASURE

Measures of Length

French	*British and U. S.*
1 metre,	= 39.37 inches or 3.28083 feet or 1.09361 yards
.3048 metre,	= 1 foot
1 centimetre,	= .3937 inch
2.54 centimetres,	= 1 inch
1 millimetre,	= .03937 inch, or 1/25 inch, nearly
25.4 millimetres,	= 1 inch
1 kilometre,	= 1093.61 yards or 0.62137 mile

Measures of Surface

French	*British and U. S.*
1 square metre,	= 10.764 square feet 1.196 square yards
.836 square metre,	= 1 square yard
.0929 square metre,	= 1 square foot
1 square centimetre,	= .155 square inch.
6.452 square centimetres,	= 1 square inch
1 square millimetre,	= .00155 square inch 1973.5 circular mils.
645.2 square millimetres,	= 1 square inch
1 centiare = 1 square metre,	= 10.764 square feet
1 are = 1 square decametre,	= 1076.41 square feet
1 hectare = 100 ares,	= 107641 square feet 2.4711 acres
1 square kilometre,	= .386109 square mile 247.11 acres
1 square myriametre,	= 38.6109 square miles

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Measures of Volume

French		*British and U. S.*
1 cubic metre,	=	35.314 cubic feet 1.308 cubic yards
.7645 cubic metre,	=	1 cubic yard
.02832 cubic metre,	=	1 cubic foot
1 cubic decimetre,	=	61.023 cubic inches .0353 cubic foot
28.32 cubic decimetres,	=	1 cubic foot
1 cubic centimetre,	=	.061 cubic inch
16.387 cubic centimetres,	=	1 cubic inch
1 cubic centimetre = 1 millilitre,	=	.061 cubic inch
1 centilitre,	=	.610 cubic inch
1 decilitre,	=	6.102 cubic inches
1 litre = 1 cubic decimetre,	=	61.023 cubic inches 1.05671 quarts, U. S.
1 hectolitre or decistere,	=	3.5314 cubic feet 2.8375 bushels, U. S.
1 stere, kilolitre, or cubic metre,	=	1.308 cubic yards 28.37 bushels, U. S.

Measures of Capacity

French		*British and U. S.*
1 litre (1 cubic decimetre),	=	61.023 cubic inches .03531 cubic foot .2642 gallon (Am.) 2.202 pounds of water at 62° Fahr.
28.317 litres,	=	1 cubic foot
4.543 litres,	=	1 gallon (British)
3.785 litres,	=	1 gallon (American)

Measures of Weight

French		*British and U. S.*
1 gramme,	=	15.432 grains
.0648 gramme,	=	1 grain
28.35 grammes,	=	1 ounce avoirdupois
1 kilogramme,	=	2.2046 pounds
.4536 kilogramme,	=	1 pound
1 tonne or metric ton, 1,000 kilogrammes,	=	.9842 ton of 2,240 pounds 19.68 cwts. 2204.6 pounds
1.016 metric tons, 1,016 kilogrammes,	=	1 ton of 2,240 pounds

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TEMPERATURES, FAHRENHEIT AND CENTIGRADE

F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
—40	—40.	26	—3.3	92	33.3	158	70.	224	106.7	290	143.3	360	182.2
—39	—39.4	27	—2.8	93	33.9	159	70.6	225	107.2	291	143.9	370	187.8
—38	—38.9	28	—2.2	94	34.4	160	71.1	226	107.8	292	144.4	380	193.3
—37	—38.3	29	—1.7	95	35.	161	71.7	227	108.3	293	145.	390	198.9
—36	—37.8	30	—1.1	96	35.6	162	72.2	228	108.9	294	145.6	400	204.4
—35	—37.2	31	—0.6	97	36.1	163	72.8	229	109.4	295	146.1	410	210.
—34	—36.7	32	0.	98	36.7	164	73.3	230	110.	296	146.7	420	215.6
—33	—36.1	33	+0.6	99	37.2	165	73.9	231	110.6	297	147.2	430	221.1
—32	—35.6	34	1.1	100	37.8	166	74.4	232	111.1	298	147.8	440	226.7
—31	—35.	35	1.7	101	38.3	167	75.	233	111.7	299	148.3	450	232.2
—30	—34.4	36	2.2	102	38.9	168	75.6	234	112.2	300	148.9	460	237.8
—29	—33.9	37	2.8	103	39.4	169	76.1	235	112.8	301	149.4	470	243.3
—28	—33.3	38	3.3	104	40.	170	76.7	236	113.3	302	150.	480	248.9
—27	—32.8	39	3.9	105	40.6	171	77.2	237	113.9	303	150.6	490	254.4
—26	—32.2	40	4.4	106	41.1	172	77.8	238	114.4	304	151.1	500	260.
—25	—31.7	41	5.	107	41.7	173	78.3	239	115.	305	151.7	510	265.6
—24	—31.1	42	5.6	108	42.2	174	78.9	240	115.6	306	152.2	520	271.1
—23	—30.6	43	6.1	109	42.8	175	79.4	241	116.1	307	152.8	530	276.7
—22	—30.	44	6.7	110	43.3	176	80.	242	116.7	308	153.3	540	282.2
—21	—29.4	45	7.2	111	43.9	177	80.6	243	117.2	309	153.9	550	287.8
—20	—28.9	46	7.8	112	44.4	178	81.1	244	117.8	310	154.4	560	293.3
—19	—28.3	47	8.3	113	45.	179	81.7	245	118.3	311	155.	570	298.9
—18	—27.8	48	8.9	114	45.6	180	82.2	246	118.9	312	155.6	580	304.4
—17	—27.2	49	9.4	115	46.1	181	82.8	247	119.4	313	156.1	590	310.
—16	—26.7	50	10.	116	46.7	182	83.3	248	120.	314	156.7	600	315.6
—15	—26.1	51	10.6	117	47.2	183	83.9	249	120.6	315	157.2	610	321.1
—14	—25.6	52	11.1	118	47.8	184	84.4	250	121.1	316	157.8	620	326.7
—13	—25.	53	11.7	119	48.3	185	85.	251	121.7	317	158.3	630	332.2
—12	—24.4	54	12.2	120	48.9	186	85.6	252	122.2	318	158.9	640	337.8
—11	—23.9	55	12.8	121	49.4	187	86.1	253	122.8	319	159.4	650	343.3
—10	—23.3	56	13.3	122	50.	188	86.7	254	123.3	320	160.	660	348.9
— 9	—22.8	57	13.9	123	50.6	189	87.2	255	123.9	321	160.6	670	354.4
— 8	—22.2	58	14.4	124	51.1	190	87.8	256	124.4	322	161.1	680	360.
— 7	—21.7	59	15.	125	51.7	191	88.3	257	125.	323	161.7	690	365.6
— 6	—21.1	60	15.6	126	52.2	192	88.9	258	125.6	324	162.2	700	371.1
— 5	—20.6	61	16.1	127	52.8	193	89.4	259	126.1	325	162.8	710	376.7
— 4	—20.	62	16.7	128	53.3	194	90.	260	126.7	326	163.3	720	382.2
— 3	—19.4	63	17.2	129	53.9	195	90.6	261	127.2	327	163.9	730	387.8
— 2	—18.9	64	17.8	130	54.4	196	91.1	262	127.8	328	164.4	740	393.3
— 1	—18.3	65	18.3	131	55.	197	91.7	263	128.3	329	165.	750	398.9
0	—17.8	66	18.9	132	55.6	198	92.2	264	128.9	330	165.6	760	404.4
+ 1	—17.2	67	19.4	133	56.1	199	92.8	265	129.4	331	166.1	770	410.
2	—16.7	68	20.	134	56.7	200	93.3	266	130.	332	166.7	780	415.6
3	—16.1	69	20.6	135	57.2	201	93.9	267	130.6	333	167.2	790	421.1
4	—15.6	70	21.1	136	57.8	202	94.4	268	131.1	334	167.8	800	426.7
5	—15.	71	21.7	137	58.3	203	95.	269	131.7	335	168.3	810	432.2
6	—14.4	72	22.2	138	58.9	204	95.6	270	132.2	336	168.9	820	437.8
7	—13.9	73	22.8	139	59.4	205	96.1	271	132.8	337	169.4	830	443.3
8	—13.3	74	23.3	140	60.	206	96.7	272	133.3	338	170.	840	448.9
9	—12.8	75	23.9	141	60.6	207	97.2	273	133.9	339	170.6	850	454.4
10	—12.2	76	24.4	142	61.1	208	97.8	274	134.4	340	171.1	860	460.
11	—11.7	77	25.	143	61.7	209	98.3	275	135.	341	171.7	870	465.6
12	—11.1	78	25.6	144	62.2	210	98.9	276	135.6	342	172.2	880	471.1
13	—10.6	79	26.1	145	62.8	211	99.4	277	136.1	343	172.8	890	476.7
14	—10.	80	26.7	146	63.3	212	100.	278	136.7	344	173.3	900	482.2
15	— 9.4	81	27.2	147	63.9	213	100.6	279	137.2	345	173.9	910	487.8
16	— 8.9	82	27.8	148	64.4	214	101.1	280	137.8	346	174.4	920	493.3
17	— 8.3	83	28.3	149	65.	215	101.7	281	138.3	347	175.	930	498.9
18	— 7.8	84	28.9	150	65.6	216	102.2	282	138.9	348	175.6	940	504.4
19	— 7.2	85	29.4	151	66.1	217	102.8	283	139.4	349	176.1	950	510.
20	— 6.7	86	30.	152	66.7	218	103.3	284	140.	350	176.7	960	515.6
21	— 6.1	87	30.6	153	67.2	219	103.9	285	140.6	351	177.2	970	521.1
22	— 5.6	88	31.1	154	67.8	220	104.4	286	141.1	352	177.8	980	526.7
23	— 5.	89	31.7	155	68.3	221	105.	287	141.7	353	178.3	990	532.2
24	— 4.4	90	32.2	156	68.9	222	105.6	288	142.2	354	178.9	1000	537.8
25	— 3.9	91	32.8	157	69.4	223	106.1	289	142.8	355	179.4	1010	543.3

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TEMPERATURES, CENTIGRADE AND FAHRENHEIT

C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.
—40	—40.	26	78.8	92	197.6	158	316.4	224	435.2	290	554	950	1742
—39	—38.2	27	80.6	93	199.4	159	318.2	225	437.	300	572	960	1760
—38	—36.4	28	82.4	94	201.2	160	320.	226	438.8	310	590	970	1778
—37	—34.6	29	84.2	95	203.	161	321.8	227	440.6	320	608	980	1796
—36	—32.8	30	86.	96	204.8	162	323.6	228	442.4	330	626	990	1814
—35	—31.	31	87.8	97	206.6	163	325.4	229	444.2	340	644	1000	1832
—34	—29.2	32	89.6	98	208.4	164	327.2	230	446.	350	662	1010	1850
—33	—27.4	33	91.4	99	210.2	165	329.	231	447.8	360	680	1020	1868
—32	—25.6	34	93.2	100	212.	166	330.8	232	449.6	370	698	1030	1886
—31	—23.8	35	95.	101	213.8	167	332.6	233	451.4	380	716	1040	1904
—30	—22.	36	96.8	102	215.6	168	334.4	234	453.2	390	734	1050	1922
—29	—20.2	37	98.6	103	217.4	169	336.2	235	455.	400	752	1060	1940
—28	—18.4	38	100.4	104	219.2	170	338.	236	456.8	410	770	1070	1958
—27	—16.6	39	102.2	105	221.	171	339.8	237	458.6	420	788	1080	1976
—26	—14.8	40	104.	106	222.8	172	341.6	238	460.4	430	806	1090	1994
—25	—13.	41	105.8	107	224.6	173	343.4	239	462.2	440	824	1100	2012
—24	—11.2	42	107.6	108	226.4	174	345.2	240	464.	450	842	1110	2030
—23	— 9.4	43	109.4	109	228.2	175	347.	241	465.8	460	860	1120	2048
—22	— 7.6	44	111.2	110	230.	176	348.8	242	467.6	470	878	1130	2066
—21	— 5.8	45	113.	111	231.8	177	350.6	243	469.4	480	896	1140	2084
—20	— 4.	46	114.8	112	233.6	178	352.4	244	471.2	490	914	1150	2102
—19	— 2.2	47	116.6	113	235.4	179	354.2	245	473.	500	932	1160	2120
—18	— 0.4	48	118.4	114	237.2	180	356.	246	474.8	510	950	1170	2138
—17	+ 1.4	49	120.2	115	239.	181	357.8	247	476.6	520	968	1180	2156
—16	3.2	50	122.	116	240.8	182	359.6	248	478.4	530	986	1190	2174
—15	5.	51	123.8	117	242.6	183	361.4	249	480.2	540	1004	1200	2192
—14	6.8	52	125.6	118	244.4	184	363.2	250	482.	550	1022	1210	2210
—13	8.6	53	127.4	119	246.2	185	365.	251	483.8	560	1040	1220	2228
—12	10.4	54	129.2	120	248.	186	366.8	252	485.6	570	1058	1230	2246
—11	12.2	55	131.	121	249.8	187	368.6	253	487.4	580	1076	1240	2264
—10	14.	56	132.8	122	251.6	188	370.4	254	489.2	590	1094	1250	2282
— 9	15.8	57	134.6	123	253.4	189	372.2	255	491.	600	1112	1260	2300
— 8	17.6	58	136.4	124	255.2	190	374.	256	492.8	610	1130	1270	2318
— 7	19.4	59	138.2	125	257.	191	375.8	257	494.6	620	1148	1280	2336
— 6	21.2	60	140.	126	258.8	192	377.6	258	496.4	630	1166	1290	2354
— 5	23.	61	141.8	127	260.6	193	379.4	259	498.2	640	1184	1300	2372
— 4	24.8	62	143.6	128	262.4	194	381.2	260	500.	650	1202	1310	2390
— 3	26.6	63	145.4	129	264.2	195	383.	261	501.8	660	1220	1320	2408
— 2	28.4	64	147.2	130	266.	196	384.8	262	503.6	670	1238	1330	2426
— 1	30.2	65	149.	131	267.8	197	386.6	263	505.4	680	1256	1340	2444
0	32.	66	150.8	132	269.6	198	388.4	264	507.2	690	1274	1350	2462
+ 1	33.8	67	152.6	133	271.4	199	390.2	265	509.	700	1292	1360	2480
2	35.6	68	154.4	134	273.2	200	392.	266	510.8	710	1310	1370	2498
3	37.4	69	156.2	135	275.	201	393.8	267	512.6	720	1328	1380	2516
4	39.2	70	158.	136	276.8	202	395.6	268	514.4	730	1346	1390	2534
5	41.	71	159.8	137	278.6	203	397.4	269	516.2	740	1364	1400	2552
6	42.8	72	161.6	138	280.4	204	399.2	270	518.	750	1382	1410	2570
7	44.6	73	163.4	139	282.2	205	401.	271	519.8	760	1400	1420	2588
8	46.4	74	165.2	140	284.	206	402.8	272	521.6	770	1418	1430	2606
9	48.2	75	167.	141	285.8	207	404.6	273	523.4	780	1436	1440	2624
10	50.	76	168.8	142	287.6	208	406.4	274	525.2	790	1454	1450	2642
11	51.8	77	170.6	143	289.4	209	408.2	275	527.	800	1472	1460	2660
12	53.6	78	172.4	144	291.2	210	410.	276	528.8	810	1490	1470	2678
13	55.4	79	174.2	145	293.	211	411.8	277	530.6	820	1508	1480	2696
14	57.2	80	176.	146	294.8	212	413.6	278	532.4	830	1526	1490	2714
15	59.	81	177.8	147	296.6	213	415.4	279	534.2	840	1544	1500	2732
16	60.8	82	179.6	148	298.4	214	417.2	280	536.	850	1562	1510	2750
17	62.6	83	181.4	149	300.2	215	419.	281	537.8	860	1580	1520	2768
18	64.4	84	183.2	150	302.	216	420.8	282	539.6	870	1598	1530	2786
19	66.2	85	185.	151	303.8	217	422.6	283	541.4	880	1616	1540	2804
20	68,	86	186.8	152	305.6	218	424.4	284	543.2	890	1634	1550	2822
21	69.8	87	188.6	153	307.4	219	426.2	285	545.	900	1652	1600	2912
22	71.6	88	190.4	154	309.2	220	428.	286	546.8	910	1670	1650	3002
23	73.4	89	192.2	155	311.	221	429.8	287	548.6	920	1688	1700	3092
24	75.2	90	194.	156	312.8	222	431.6	288	550.4	930	1706	1750	3182
25	77.	91	195.8	157	314.6	223	433.4	289	552.2	940	1724	1800	3272

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SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS OF NUMBERS FROM 0.1 TO 100

No.	Square	Cube	Sq. Root	Cube Root	No.	Square	Cube	Sq. Root	Cube Root
0.1	.01	.001	.3162	.4642	3.1	9.61	29.791	1.761	1.458
.15	.0225	.0034	.3873	.5313	.2	10.24	32.768	1.789	1.474
.2	.04	.008	.4472	.5848	.3	10.89	35.937	1.817	1.489
.25	.0625	.0156	.500	.6300	.4	11.56	39.304	1.844	1.504
.3	.09	.027	.5477	.6694	.5	12.25	42.875	1.871	1.518
.35	.1225	.0429	.5916	.7047	.6	12.96	46.656	1.897	1.533
.4	.16	.064	.6325	.7368	.7	13.69	50.653	1.924	1.547
.45	.2025	.0911	.6708	.7663	.8	14.44	54.872	1.949	1.560
.5	.25	.125	.7071	.7937	.9	15.21	59.319	1.975	1.574
.55	.3025	.1664	.7416	.8193	**4.**	16.	64.	2.	1.5874
.6	.36	.216	.7746	.8434	.1	16.81	68.921	2.025	1.601
.65	.4225	.2746	.8062	.8662	.2	17.64	74.088	2.049	1.613
.7	.49	.343	.8367	.8879	.3	18.49	79.507	2.074	1.626
.75	.5625	.4219	.8660	.9086	.4	19.36	85.184	2.098	1.639
.8	.64	.512	.8944	.9283	.5	20.25	91.125	2.121	1.651
.85	.7225	.6141	.9219	.9473	.6	21.16	97.336	2.145	1.663
.9	.81	.729	.9487	.9655	.7	22.09	103.823	2.168	1.675
.95	.9025	.8574	.9747	.9830	.8	23.04	110.592	2.191	1.687
1.	1.	1.	1.	1.	.9	24.01	117.649	2.214	1.698
1.05	1.1025	1.158	1.025	1.016	**5.**	25.	125.	2.2361	1.7100
1.1	1.21	1.331	1.049	1.032	.1	26.01	132.651	2.258	1.721
1.15	1.3225	1.521	1.072	1.048	.2	27.04	140.608	2.280	1.732
1.2	1.44	1.728	1.095	1.063	.3	28.09	148.877	2.302	1.744
1.25	1.5625	1.953	1.118	1.077	.4	29.16	157.464	2.324	1.754
1.3	1.69	2.197	1.140	1.091	.5	30.25	166.375	2.345	1.765
1.35	1.8225	2.460	1.162	1.105	.6	31.36	175.616	2.366	1.776
1.4	1.96	2.744	1.183	1.119	.7	32.49	185.193	2.387	1.786
1.45	2.1025	3.049	1.204	1.132	.8	33.64	195.112	2.408	1.797
1.5	2.25	3.375	1.2247	1.1447	.9	34.81	205.379	2.429	1.807
1.55	2.4025	3.724	1.245	1.157	**6.**	36.	216.	2.4495	1.8171
1.6	2.56	4.096	1.265	1.170	.1	37.21	226.981	2.470	1.827
1.65	2.7225	4.492	1.285	1.182	.2	38.44	238.328	2.490	1.837
1.7	2.89	4.913	1.304	1.193	.3	39.69	250.047	2.510	1.847
1.75	3.0625	5.359	1.323	1.205	.4	40.96	262.144	2.530	1.857
1.8	3.24	5.832	1.342	1.216	.5	42.25	274.625	2.550	1.866
1.85	3.4225	6.332	1.360	1.228	.6	43.56	287.496	2.569	1.876
1.9	3.61	6.859	1.378	1.239	.7	44.89	300.763	2.588	1.885
1.95	3.8025	7.415	1.396	1.249	.8	46.24	314.432	2.608	1.895
2.	4.	8.	1.4142	1.2599	.9	47.61	328.509	2.627	1.904
.1	4.41	9.261	1.449	1.281	**7.**	49.	343.	2.6458	1.9129
.2	4.84	10.648	1.483	1.301	.1	50.41	357.911	2.665	1.922
.3	5.29	12.167	1.517	1.320	.2	51.84	373.248	2.683	1.931
.4	5.76	13.824	1.549	1.339	.3	53.29	389.017	2.702	1.940
.5	6.25	15.625	1.581	1.357	.4	54.76	405.224	2.720	1.949
.6	6.76	17.576	1.612	1.375	.5	56.25	421.875	2.739	1.957
.7	7.29	19.683	1.643	1.392	.6	57.76	438.976	2.757	1.966
.8	7.84	21.952	1.673	1.409	.7	59.29	456.533	2.775	1.975
.9	8.41	24.389	1.703	1.426	.8	60.84	474.552	2.793	1.983
3.	9.	27.	1.7321	1.4422	.9	62.41	493.039	2.811	1.992

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No.	Square	Cube	Sq. Root	Cube Root	No.	Sq.	Cube	Sq. Root	Cube Root
8.	64.	512.	2.8284	2.	45	2025	91125	6.7082	3.5569
.1	65.61	531.441	2.846	2.008	46	2116	97336	6.7823	3.5830
.2	67.24	551.368	2.864	2.017	47	2209	103823	6.8557	3.6088
.3	68.89	571.787	2.881	2.025	48	2304	110592	6.9282	3.6342
.4	70.56	592.704	2.898	2.033	49	2401	117649	7.	3.6593
.5	72.25	614.125	2.915	2.041	50	2500	125000	7.0711	3.6840
.6	73.96	636.056	2.933	2.049	51	2601	132651	7.1414	3.7084
.7	75.69	658.503	2.950	2.057	52	2704	140608	7.2111	3.7325
.8	77.44	681.472	2.966	2.065	53	2809	148877	7.2801	3.7563
.9	79.21	704.969	2.983	2.072	54	2916	157464	7.3485	3.7798
9.	81.	729.	3.	2.0801	55	3025	166375	7.4162	3.8030
.1	82.81	753.571	3.017	2.088	56	3136	175616	7.4833	3.8259
.2	84.64	778.688	3.033	2.095	57	3249	185193	7.5498	3.8485
.3	86.49	804.357	3.050	2.103	58	3364	195112	7.6158	3.8709
.4	88.36	830.584	3.066	2.110	59	3481	205379	7.6811	3.8930
.5	90.25	857.375	3.082	2.118	60	3600	216000	7.7460	3.9149
.6	92.16	884.736	3.098	2.125	61	3721	226981	7.8102	3.9365
.7	94.09	912.673	3.114	2.133	62	3844	238328	7.8740	3.9579
.8	96.04	941.192	3.130	2.140	63	3969	250047	7.9373	3.9791
.9	98.01	970.299	3.146	2.147	64	4096	262144	8.	4.
10	100	1000	3.1623	2.1544	65	4225	274625	8.0623	4.0207
11	121	1331	3.3166	2.2240	66	4356	287496	8.1240	4.0412
12	144	1728	3.4641	2.2894	67	4489	300763	8.1854	4.0615
13	169	2197	3.6056	2.3513	68	4624	314432	8.2462	4.0817
14	196	2744	3.7417	2.4101	69	4761	328509	8.3066	4.1016
15	225	3375	3.8730	2.4662	70	4900	343000	8.3666	4.1213
16	256	4096	4.	2.5198	71	5041	357911	8.4261	4.1408
17	289	4913	4.1231	2.5713	72	5184	373248	8.4853	4.1602
18	324	5832	4.2426	2.6207	73	5329	389017	8.5440	4.1793
19	361	6859	4.3589	2.6684	74	5476	405224	8.6023	4.1983
20	400	8000	4.4721	2.7144	75	5625	421875	8.6603	4.2172
21	441	9261	4.5826	2.7589	76	5776	438976	8.7178	4.2358
22	484	10648	4.6904	2.8020	77	5929	456533	8.7750	4.2543
23	529	12167	4.7958	2.8439	78	6084	474552	8.8318	4.2727
24	576	13824	4.8990	2.8845	79	6241	493039	8.8882	4.2908
25	625	15625	5.	2.9240	80	6400	512000	8.9443	4.3089
26	676	17576	5.0990	2.9625	81	6561	531441	9.	4.3267
27	729	19683	5.1962	3.	82	6724	551368	9.0554	4.3445
28	784	21952	5.2915	3.0366	83	6889	571787	9.1104	4.3621
29	841	24389	5.3852	3.0723	84	7056	592704	9.1652	4.3795
30	900	27000	5.4772	3.1072	85	7225	614125	9.2195	4.3968
31	961	29791	5.5678	3.1414	86	7396	636056	9.2736	4.4140
32	1024	32768	5.6569	3.1748	87	7569	658503	9.3276	4.4310
33	1089	35937	5.7446	3.2075	88	7744	681472	9.3808	4.4480
34	1156	39304	5.8310	3.2396	89	7921	704969	9.4340	4.4647
35	1225	42875	5.9161	3.2711	90	8100	729000	9.4868	4.4814
36	1296	46656	6.	3.3019	91	8281	753571	9.5394	4.4979
37	1369	50653	6.0828	3.3322	92	8464	778688	9.5917	4.5144
38	1444	54872	6.1644	3.3620	93	8649	804357	9.6437	4.5307
39	1521	59319	6.2450	3.3912	94	8836	830584	9.6954	4.5468
40	1600	64000	6.3246	3.4200	95	9025	857375	9.7468	4.5629
41	1681	68921	6.4031	3.4482	96	9216	884736	9.7980	4.5789
42	1764	74088	6.4807	3.4760	97	9409	912673	9.8489	4.5947
43	1849	79507	6.5574	3.5034	98	9604	941192	9.8995	4.6104
44	1936	85184	6.6332	3.5303	99	9801	970299	9.9499	4.6261

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COMMON FRACTIONS AND THEIR EQUIVALENTS IN DECIMAL INCHES AND MILLIMETERS

Fraction	Inches	Millimeters	Fraction	Inches	Millimeters
1/64	.0156	.397	33/64	.5156	13.10
1/32	.0313	.79	17/32	.5313	13.50
3/64	.0469	1.19	35/64	.5469	13.89
1/16 2/32	.0625	1.59	9/16 18/32	.5625	14.29
5/64	.0781	1.98	37/64	.5781	14.69
3/32	.0938	2.38	19/32	.5938	15.09
7/64	.1094	2.78	39/64	.6094	15.48
1/8 4/32	.1250	3.18	5/8 20/32	.6250	15.88
9/64	.1406	3.57	41/64	.6406	16.28
5/32	.1563	3.97	21/32	.6563	16.67
11/64	.1719	4.37	43/64	.6719	17.07
3/16 6/32	.1875	4.76	11/16 22/32	.6875	17.47
13/64	.2031	5.16	45/64	.7031	17.86
7/32	.2188	5.56	23/32	.7188	18.26
15/64	.2344	5.95	47/64	.7344	18.66
1/4 8/32	.2500	6.35	3/4 24/32	.7500	19.01
17/64	.2656	6.75	49/64	.7656	19.45
9/32	.2813	7.15	25/32	.7813	19.85
19/64	.2969	7.54	51/64	.7969	20.25
5/16 10/32	.3125	7.94	13/16 26/32	.8125	20.64
21/64	.3281	8.34	53/64	.8281	21.04
11/32	.3438	8.73	27/32	.8438	21.44
23/64	.3594	9.13	55/64	.8594	21.83
3/8 12/32	.3750	9.53	7/8 28/32	.8750	22.23
25/64	.3906	9.92	57/64	.8906	22.63
13/32	.4063	10.32	29/32	.9063	23.02
27/64	.4219	10.72	59/64	.9219	23.42
7/16 14/32	.4375	11.12	15/16 30/32	.9375	23.82
29/64	.4531	11.51	61/64	.9531	24.22
15/32	.4688	11.91	31/32	.9688	24.61
31/64	.4844	12.31	63/64	.9844	25.01
1/2 16/32	.5000	12.70	1 32/32	1.0000	25.41

CIRCUMFERENCE AND AREAS OF CIRCLES

Diam.	Circum.	Area	Diam.	Circum.	Area	Diam.	Circum.	Area
1/64	.04909	.00019	2½	7.8540	4.9087	6⅝	20.813	34.472
1/32	.09818	.00077	9/16	8.0503	5.1572	¾	21.206	35.785
3/64	.14726	.00173	5/8	8.2467	5.4119	7/8	21.598	37.122
1/16	.19635	.00307	11/16	8.4430	5.6727	**7.**	21.991	38.485
3/32	.29452	.00690	3/4	8.6394	5.9396	1/8	22.384	39.871
1/8	.39270	.01227	13/16	8.8357	6.2126	1/4	22.776	41.282
5/32	.49087	.01917	7/8	9.0321	6.4918	3/8	23.169	42.718
3/16	.58905	.02761	15/16	9.2284	6.7771	1/2	23.562	44.179
7/32	.68722	.03758				5/8	23.955	45.664
			3.	9.4248	7.0686	3/4	24.347	47.173
1/4	.78540	.04909	1/16	9.6211	7.3662	7/8	24.740	48.707
9/32	.88357	.06213	1/8	9.8175	7.6699	**8.**	25.133	50.265
5/16	.98175	.07670	3/16	10.014	7.9798	1/8	25.525	51.849
11/32	1.0799	.09281	1/4	10.210	8.2958	1/4	25.918	53.456
3/8	1.1781	.11045	5/16	10.407	8.6179	3/8	26.311	55.088
13/32	1.2763	.12962	3/8	10.603	8.9462	1/2	26.704	56.745
7/16	1.3744	.15033	7/16	10.799	9.2806	5/8	27.096	58.426
15/32	1.4726	.17257	1/2	10.996	9.6211	3/4	27.489	60.132
			9/16	11.192	9.9678	7/8	27.882	61.862
1/2	1.5708	.19635	5/8	11.388	10.321	**9.**	28.274	63.617
17/32	1.6690	.22166	11/16	11.585	10.680	1/8	28.667	65.397
9/16	1.7671	.24850	3/4	11.781	11.045	1/4	29.060	67.201
19/32	1.8653	.27688	13/16	11.977	11.416	3/8	29.452	69.029
5/8	1.9635	.30680	7/8	12.174	11.793	1/2	29.845	70.882
21/32	2.0617	.33824	15/16	12.370	12.177	5/8	30.238	72.760
11/16	2.1598	.37122	**4.**	12.566	12.566	3/4	30.631	74.662
23/32	2.2580	.40574	1/16	12.763	12.962	7/8	31.023	76.589
			1/8	12.959	13.364	**10.**	31.416	78.540
3/4	2.3562	.44179	3/16	13.155	13.772	1/8	31.809	80.516
25/32	2.4544	.47937	1/4	13.352	14.186	1/4	32.201	82.516
13/16	2.5525	.51849	5/16	13.548	14.607	3/8	32.594	84.541
27/32	2.6507	.55914	3/8	13.744	15.033	1/2	32.987	86.590
7/8	2.7489	.60132	7/16	13.941	15.466	5/8	33.379	88.664
29/32	2.8471	.64504	1/2	14.137	15.904	3/4	33.772	90.763
15/16	2.9452	.69029	9/16	14.334	16.349	7/8	34.165	92.886
31/32	3.0434	.73708	5/8	14.530	16.800	**11.**	34.558	95.033
			11/16	14.726	17.257	1/8	34.950	97.205
1.	3.1416	.7854	3/4	14.923	17.721	1/4	35.343	99.402
1/16	3.3379	.8866	13/16	15.119	18.190	3/8	35.736	101.62
1/8	3.5343	.9940	7/8	15.315	18.665	1/2	36.128	103.87
3/16	3.7306	1.1075	15/16	15.512	19.147	5/8	36.521	106.14
1/4	3.9270	1.2272	**5.**	15.708	19.635	3/4	36.914	108.43
5/16	4.1233	1.3530	1/16	15.904	20.129	7/8	37.306	110.75
3/8	4.3197	1.4849	1/8	16.101	20.629	**12.**	37.699	113.10
7/16	4.5160	1.6230	3/16	16.297	21.135	1/8	38.092	115.47
1/2	4.7124	1.7671	1/4	16.493	21.648	1/4	38.485	117.86
9/16	4.9087	1.9175	5/16	16.690	22.166	3/8	38.877	120.28
5/8	5.1051	2.0739	3/8	16.886	22.691	1/2	39.270	122.72
11/16	5.3014	2.2365	7/16	17.082	23.221	5/8	39.663	125.19
3/4	5.4978	2.4053	1/2	17.279	23.758	3/4	40.055	127.68
13/16	5.6941	2.5802	9/16	17.475	24.301	7/8	40.448	130.19
7/8	5.8905	2.7612	5/8	17.671	24.850	**13.**	40.841	132.73
15/16	6.0868	2.9483	11/16	17.868	25.406	1/8	41.233	135.30
			3/4	18.064	25.967	1/4	41.626	137.89
2.	6.2832	3.1416	13/16	18.261	26.535	3/8	42.019	140.50
1/16	6.4795	3.3410	7/8	18.457	27.109	1/2	42.412	143.14
1/8	6.6759	3.5466	15/16	18.653	27.688	5/8	42.804	145.80
3/16	6.8722	3.7583	**6.**	18.850	28.274	3/4	43.197	148.49
1/4	7.0686	3.9761	1/8	19.242	29.465	7/8	43.590	151.20
5/16	7.2649	4.2000	1/4	19.635	30.680	**14.**	43.982	153.94
3/8	7.4613	4.4301	3/8	20.028	31.919	1/8	44.375	156.70
7/16	7.6576	4.6664	1/2	20.420	33.183	1/4	44.768	159.48

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Diam.	Circum.	Area	Diam.	Circum.	Area	Diam.	Circum.	Area
14⅜	45.160	162.30	**22¼**	69.900	388.82	**30⅛**	94.640	712.76
½	45.553	165.13	⅜	70.293	393.20	¼	95.033	718.69
⅝	45.946	167.99	½	70.686	397.61	⅜	95.426	724.64
¾	46.338	170.87	⅝	71.079	402.04	½	95.819	730.62
⅞	46.731	173.78	¾	71.471	406.49	⅝	96.211	736.62
15.	47.124	176.71	⅞	71.864	410.97	¾	96.604	742.64
⅛	47.517	179.67	**23.**	72.257	415.48	⅞	96.997	748.69
¼	47.909	182.65	⅛	72.649	420.00	**31.**	97.389	754.77
⅜	48.302	185.66	¼	73.042	424.56	⅛	97.782	760.87
½	48.695	188.69	⅜	73.435	429.13	¼	98.175	766.99
⅝	49.087	191.75	½	73.827	433.74	⅜	98.567	773.14
¾	49.480	194.83	⅝	74.220	438.36	½	98.960	779.31
⅞	49.873	197.93	¾	74.613	443.01	⅝	99.353	785.51
16.	50.265	201.06	⅞	75.006	447.69	¾	99.746	791.73
⅛	50.658	204.22	**24.**	75.398	452.39	⅞	100.138	797.98
¼	51.051	207.39	⅛	75.791	457.11	**32.**	100.531	804.25
⅜	51.444	210.60	¼	76.184	461.86	⅛	100.924	810.54
½	51.836	213.82	⅜	76.576	466.64	¼	101.316	816.86
⅝	52.229	217.08	½	76.969	471.44	⅜	101.709	823.21
¾	52.622	220.35	⅝	77.362	476.26	½	102.102	829.58
⅞	53.014	223.65	¾	77.754	481.11	⅝	102.494	835.97
17.	53.407	226.98	⅞	78.147	485.98	¾	102.887	842.39
⅛	53.800	230.33	**25.**	78.540	490.87	⅞	103.280	848.83
¼	54.192	233.71	⅛	78.933	495.79	**33.**	103.673	855.30
⅜	54.585	237.10	¼	79.325	500.74	⅛	104.065	861.79
½	54.978	240.53	⅜	79.718	505.71	¼	104.458	868.31
⅝	55.371	243.98	½	80.111	510.71	⅜	104.851	874.85
¾	55.763	247.45	⅝	80.503	515.72	½	105.243	881.41
⅞	56.156	250.95	¾	80.896	520.77	⅝	105.636	888.00
18.	56.549	254.47	⅞	81.289	525.84	¾	106.029	894.62
⅛	56.941	258.02	**26.**	81.681	530.93	⅞	106.421	901.26
¼	57.334	261.59	⅛	82.074	536.05	**34.**	106.814	907.92
⅜	57.727	265.18	¼	82.467	541.19	⅛	107.207	914.61
½	58.119	268.80	⅜	82.860	546.35	¼	107.600	921.32
⅝	58.512	272.45	½	83.252	551.55	⅜	107.992	928.06
¾	58.905	276.12	⅝	83.645	556.76	½	108.385	934.82
⅞	59.298	279.81	¾	84.038	562.00	⅝	108.778	941.61
19.	59.690	283.53	⅞	84.430	567.27	¾	109.170	948.42
⅛	60.083	287.27	**27.**	84.823	572.56	⅞	109.563	955.25
¼	60.476	291.04	⅛	85.216	577.87	**35.**	109.956	962.11
⅜	60.868	294.83	¼	85.608	583.21	⅛	110.348	969.00
½	61.261	298.65	⅜	86.001	588.57	¼	110.741	975.91
⅝	61.654	302.49	½	86.394	593.96	⅜	111.134	982.84
¾	62.046	306.35	⅝	86.786	599.37	½	111.527	989.80
⅞	62.439	310.24	¾	87.179	604.81	⅝	111.919	996.78
20.	62.832	314.16	⅞	87.572	610.27	¾	112.312	1003.8
⅛	63.225	318.10	**28.**	87.965	615.75	⅞	112.705	1010.8
¼	63.617	322.06	⅛	88.357	621.26	**36.**	113.097	1017.9
⅜	64.010	326.05	¼	88.750	626.80	⅛	113.490	1025.0
½	64.403	330.06	⅜	89.143	632.36	¼	113.883	1032.1
⅝	64.795	334.10	½	89.535	637.94	⅜	114.275	1039.2
¾	65.188	338.16	⅝	89.928	643.55	½	114.668	1046.3
⅞	65.581	342.25	¾	90.321	649.18	⅝	115.061	1053.5
21.	65.973	346.36	⅞	90.713	654.84	¾	115.454	1060.7
⅛	66.366	350.50	**29.**	91.106	660.52	⅞	115.846	1068.0
¼	66.759	354.66	⅛	91.499	666.23	**37.**	116.239	1075.2
⅜	67.152	358.84	¼	91.892	671.96	⅛	116.632	1082.5
½	67.544	363.05	⅜	92.284	677.71	¼	117.024	1089.8
⅝	67.937	367.28	½	92.677	683.49	⅜	117.417	1097.1
¾	68.330	371.54	⅝	93.070	689.30	½	117.810	1104.5
⅞	68.722	375.83	¾	93.462	695.13	⅝	118.202	1111.8
22.	69.115	380.13	⅞	93.855	700.98	¾	118.596	1119.2
⅛	69.508	384.46	**30.**	94.248	706.86	⅞	118.988	1126.7

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Diam.	Circum.	Area	Diam.	Circum.	Area	Diam.	Circum.	Area
38.	119.381	1134.1	45⅞	144.121	1652.9	53¾	168.861	2269.1
⅛	119.773	1141.6	**46.**	144.513	1661.9	⅞	169.253	2279.6
¼	120.166	1149.1	⅛	144.906	1670.9	**54.**	169.646	2290.2
⅜	120.559	1156.6	¼	145.299	1680.0	⅛	170.039	2300.8
½	120.951	1164.2	⅜	145.691	1689.1	¼	170.431	2311.5
⅝	121.344	1171.7	½	146.084	1698.2	⅜	170.824	2322.1
¾	121.737	1179.3	⅝	146.477	1707.4	½	171.217	2332.8
⅞	122.129	1186.9	¾	146.869	1716.5	⅝	171.609	2343.5
39.	122.522	1194.6	⅞	147.262	1725.7	¾	172.002	2354.3
⅛	122.915	1202.3	**47.**	147.655	1734.9	⅞	172.395	2365.0
¼	123.308	1210.0	⅛	148.048	1744.2	**55.**	172.788	2375.8
⅜	123.700	1217.7	¼	148.440	1753.5	⅛	173.180	2386.6
½	124.093	1225.4	⅜	148.833	1762.7	¼	173.573	2397.5
⅝	124.486	1233.2	½	149.226	1772.1	⅜	173.966	2408.3
¾	124.878	1241.0	⅝	149.618	1781.4	½	174.358	2419.2
⅞	125.271	1248.8	¾	150.011	1790.8	⅝	174.751	2430.1
40.	125.664	1256.6	⅞	150.404	1800.1	¾	175.144	2441.1
⅛	126.056	1264.5	**48.**	150.796	1809.6	⅞	175.536	2452.0
¼	126.449	1272.4	⅛	151.189	1819.0	**56.**	175.929	2463.0
⅜	126.842	1280.3	¼	151.582	1828.5	⅛	176.322	2474.0
½	127.235	1288.2	⅜	151.975	1837.9	¼	176.715	2485.0
⅝	127.627	1296.2	½	152.367	1847.5	⅜	177.107	2496.1
¾	128.020	1304.2	⅝	152.760	1857.0	½	177.500	2507.2
⅞	128.413	1312.2	¾	153.153	1866.5	⅝	177.893	2518.3
41.	128.805	1320.3	⅞	153.545	1876.1	¾	178.285	2529.4
⅛	129.198	1328.3	**49.**	153.938	1885.7	⅞	178.678	2540.6
¼	129.591	1336.4	⅛	154.331	1895.4	**57.**	179.071	2551.8
⅜	129.983	1344.5	¼	154.723	1905.0	⅛	179.463	2563.0
½	130.376	1352.7	⅜	155.116	1914.7	¼	179.856	2574.2
⅝	130.769	1360.8	½	155.509	1924.4	⅜	180.249	2585.4
¾	131.161	1369.0	⅝	155.902	1934.2	½	180.642	2596.7
⅞	131.554	1377.2	¾	156.294	1943.9	⅝	181.034	2608.0
42.	131.947	1385.4	⅞	156.687	1953.7	¾	181.427	2619.4
⅛	132.340	1393.7	**50.**	157.080	1963.5	⅞	181.820	2630.7
¼	132.732	1402.0	⅛	157.472	1973.3	**58.**	182.212	2642.1
⅜	133.125	1410.3	¼	157.865	1983.2	⅛	182.605	2653.5
½	133.518	1418.6	⅜	158.258	1993.1	¼	182.998	2664.9
⅝	133.910	1427.0	½	158.650	2003.0	⅜	183.390	2676.4
¾	134.303	1435.4	⅝	159.043	2012.9	½	183.783	2687.8
⅞	134.696	1443.8	¾	159.436	2022.8	⅝	184.176	2699.3
43.	135.088	1452.2	⅞	159.829	2032.8	¾	184.569	2710.9
⅛	135.481	1460.7	**51.**	160.221	2042.8	⅞	184.961	2722.4
¼	135.874	1469.1	⅛	160.614	2052.8	**59.**	185.354	2734.0
⅜	136.267	1477.6	¼	161.007	2062.9	⅛	185.747	2745.6
½	136.659	1486.2	⅜	161.399	2073.0	¼	186.139	2757.2
⅝	137.052	1494.7	½	161.792	2083.1	⅜	186.532	2768.8
¾	137.445	1503.3	⅝	162.185	2093.2	½	186.925	2780.5
⅞	137.837	1511.9	¾	162.577	2103.3	⅝	187.317	2792.2
44.	138.230	1520.5	⅞	162.970	2113.5	¾	187.710	2803.9
⅛	138.623	1529.2	**52.**	163.363	2123.7	⅞	188.103	2815.7
¼	139.015	1537.9	⅛	163.756	2133.9	**60.**	188.496	2827.4
⅜	139.408	1546.6	¼	164.148	2144.2	⅛	188.888	2839.2
½	139.801	1555.3	⅜	164.541	2154.5	¼	189.281	2851.0
⅝	140.194	1564.0	½	164.934	2164.8	⅜	189.674	2862.9
¾	140.586	1572.8	⅝	165.326	2175.1	½	190.066	2874.8
⅞	140.979	1581.6	¾	165.719	2185.4	⅝	190.459	2886.6
45.	141.372	1590.4	⅞	166.112	2195.8	¾	190.852	2898.6
⅛	141.764	1599.3	**53.**	166.504	2206.2	⅞	191.244	2910.5
¼	142.157	1608.2	⅛	166.897	2216.6	**61.**	191.637	2922.5
⅜	142.550	1617.0	¼	167.290	2227.0	⅛	192.030	2934.5
½	142.942	1626.0	⅜	167.683	2237.5	¼	192.423	2946.5
⅝	143.335	1634.9	½	168.075	2248.0	⅜	192.815	2958.5
¾	143.728	1643.9	⅝	168.468	2258.5	½	193.208	2970.6

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Diam.	Circum.	Area	Diam.	Circum.	Area	Diam.	Circum.	Area
61⅝	193.601	2982.7	69½	218.341	3793.7	77⅜	243.081	4702.1
¾	193.993	2994.8	⅝	218.733	3807.3	½	243.473	4717.3
⅞	194.386	3006.9	¾	219.126	3821.0	⅝	243.866	4732.5
62.	194.779	3019.1	⅞	219.519	3834.7	¾	244.259	4747.8
⅛	195.171	3031.3	70.	219.911	3848.5	⅞	244.652	4763.1
¼	195.564	3043.5	⅛	220.304	3862.2	78.	245.044	4778.4
⅜	195.957	3055.7	¼	220.697	3876.0	⅛	245.437	4793.7
½	196.350	3068.0	⅜	221.090	3889.8	¼	245.830	4809.0
⅝	196.742	3080.3	½	221.482	3903.6	⅜	246.222	4824.4
¾	197.135	3092.6	⅝	221.875	3917.5	½	246.615	4839.8
⅞	197.528	3104.9	¾	222.268	3931.4	⅝	247.008	4855.2
63.	197.920	3117.2	⅞	222.660	3945.3	¾	247.400	4870.7
⅛	198.313	3129.6	71.	223.053	3959.2	⅞	247.793	4886.2
¼	198.706	3142.0	⅛	223.446	3973.1	79.	248.186	4901.7
⅜	199.098	3154.5	¼	223.838	3987.1	⅛	248.579	4917.2
½	199.491	3166.9	⅜	224.231	4001.1	¼	248.971	4932.7
⅝	199.884	3179.4	½	224.624	4015.2	⅜	249.364	4948.3
¾	200.277	3191.9	⅝	225.017	4029.2	½	249.757	4963.9
⅞	200.669	3204.4	¾	225.409	4043.3	⅝	250.149	4979.5
64.	201.062	3217.0	⅞	225.802	4057.4	¾	250.542	4995.2
⅛	201.455	3229.6	72.	226.195	4071.5	⅞	250.935	5010.9
¼	201.847	3242.2	⅛	226.587	4085.7	80.	251.327	5026.5
⅜	202.240	3254.8	¼	226.980	4099.8	⅛	251.720	5042.3
½	202.633	3267.5	⅜	227.373	4114.0	¼	252.113	5058.0
⅝	203.025	3280.1	½	227.765	4128.2	⅜	252.506	5073.8
¾	203.418	3292.8	⅝	228.158	4142.5	½	252.898	5089.6
⅞	203.811	3305.6	¾	228.551	4156.8	⅝	253.291	5105.4
65.	204.204	3318.3	⅞	228.944	4171.1	¾	253.684	5121.2
⅛	204.596	3331.1	73.	229.336	4185.4	⅞	254.076	5137.1
¼	204.989	3343.9	⅛	229.729	4199.7	81.	254.469	5153.0
⅜	205.382	3356.7	¼	230.122	4214.1	⅛	254.862	5168.9
½	205.774	3369.6	⅜	230.514	4228.5	¼	255.254	5184.9
⅝	206.167	3382.4	½	230.907	4242.9	⅜	255.647	5200.8
¾	206.560	3395.3	⅝	231.300	4257.4	½	256.040	5216.8
⅞	206.952	3408.2	¾	231.692	4271.8	⅝	256.433	5232.8
66.	207.345	3421.2	⅞	232.085	4286.3	¾	256.825	5248.9
⅛	207.738	3434.2	74.	232.478	4300.8	⅞	257.218	5264.9
¼	208.131	3447.2	⅛	232.871	4315.4	82.	257.611	5281.0
⅜	208.523	3460.2	¼	233.263	4329.9	⅛	258.003	5297.1
½	208.916	3473.2	⅜	233.656	4344.5	¼	258.396	5313.3
⅝	209.309	3486.3	½	234.049	4359.2	⅜	258.789	5329.4
¾	209.701	3499.4	⅝	234.441	4373.8	½	259.181	5345.6
⅞	210.094	3512.5	¾	234.834	4388.5	⅝	259.574	5361.8
67.	210.487	3525.7	⅞	235.227	4403.1	¾	259.967	5378.1
⅛	210.879	3538.8	75.	235.619	4417.9	⅞	260.359	5394.3
¼	211.272	3552.0	⅛	236.012	4432.6	83.	260.752	5410.6
⅜	211.665	3565.2	¼	236.405	4447.4	⅛	261.145	5426.9
½	212.058	3578.5	⅜	236.798	4462.2	¼	261.538	5443.3
⅝	212.450	3591.7	½	237.190	4477.0	⅜	261.930	5459.6
¾	212.843	3605.0	⅝	237.583	4491.8	½	262.323	5476.0
⅞	213.236	3618.3	¾	237.976	4506.7	⅝	262.716	5492.4
68.	213.628	3631.7	⅞	238.368	4521.5	¾	263.108	5508.8
⅛	214.021	3645.0	76.	238.761	4536.5	⅞	263.501	5525.3
¼	214.414	3658.4	⅛	239.154	4551.4	84.	263.894	5541.8
⅜	214.806	3671.8	¼	239.546	4566.4	⅛	264.286	5558.3
½	215.199	3685.3	⅜	239.939	4581.3	¼	264.679	5574.8
⅝	215.592	3698.7	½	240.332	4596.3	⅜	265.072	5591.4
¾	215.984	3712.2	⅝	240.725	4611.4	½	265.465	5607.9
⅞	216.377	3725.7	¾	241.117	4626.4	⅝	265.857	5624.5
69.	216.770	3739.3	⅞	241.510	4641.5	¾	266.250	5641.2
⅛	217.163	3752.8	77.	241.903	4656.6	⅞	266.643	5657.8
¼	217.555	3766.4	⅛	242.295	4671.8	85.	267.035	5674.5
⅜	217.948	3780.0	¼	242.688	4686.9	⅛	267.428	5691.2

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Diam.	Circum.	Area	Diam.	Circum.	Area	Diam.	Circum.	Area
85¼	267.821	5707.9	**90¼**	283.529	6397.1	**95¼**	299.237	7125.6
⅜	268.213	5724.7	⅜	283.921	6414.9	⅜	299.629	7144.3
½	268.606	5741.5	½	284.314	6432.6	½	300.022	7163.0
⅝	268.999	5758.3	⅝	284.707	6450.4	⅝	300.415	7181.8
¾	269.392	5775.1	¾	285.100	6468.2	¾	300.807	7200.6
⅞	269.784	5791.9	⅞	285.492	6486.0	⅞	301.200	7219.4
86.	270.177	5808.8	**91.**	285.885	6503.9	**96.**	301.593	7238.2
⅛	270.570	5825.7	⅛	286.278	6521.8	⅛	301.986	7257.1
¼	270.962	5842.6	¼	286.670	6539.7	¼	302.378	7276.0
⅜	271.355	5859.6	⅜	287.063	6557.6	⅜	302.771	7294.9
½	271.748	5876.5	½	287.456	6575.5	½	303.164	7313.8
⅝	272.140	5893.5	⅝	287.848	6593.5	⅝	303.556	7332.8
¾	272.533	5910.6	¾	288.241	6611.5	¾	303.949	7351.8
⅞	272.926	5927.6	⅞	288.634	6629.6	⅞	304.342	7370.8
87.	273.319	5944.7	**92.**	289.027	6647.6	**97.**	304.734	7389.8
⅛	273.711	5961.8	⅛	289.419	6665.7	⅛	305.127	7408.9
¼	274.104	5978.9	¼	289.812	6683.8	¼	305.520	7428.0
⅜	274.497	5996.0	⅜	290.205	6701.9	⅜	305.913	7447.1
½	274.889	6013.2	½	290.597	6720.1	½	306.305	7466.2
⅝	275.282	6030.4	⅝	290.990	6738.2	⅝	306.698	7485.3
¾	275.675	6047.6	¾	291.383	6756.4	¾	307.091	7504.5
⅞	276.067	6064.9	⅞	291.775	6774.7	⅞	307.483	7523.7
88.	276.460	6082.1	**93.**	292.168	6792.9	**98.**	307.876	7543.0
⅛	276.853	6099.4	⅛	292.561	6811.2	⅛	308.269	7562.2
¼	277.246	6116.7	¼	292.954	6829.5	¼	308.661	7581.5
⅜	277.638	6134.1	⅜	293.346	6847.8	⅜	309.054	7600.8
½	278.031	6151.4	½	293.739	6866.1	½	309.447	7620.1
⅝	278.424	6168.8	⅝	294.132	6884.5	⅝	309.840	7639.5
¾	278.816	6186.2	¾	294.524	6902.9	¾	310.232	7658.9
⅞	279.209	6203.7	⅞	294.917	6921.3	⅞	310.625	7678.3
89.	279.602	6221.1	**94.**	295.310	6939.8	**99.**	311.018	7697.7
⅛	279.994	6238.6	⅛	295.702	6958.2	⅛	311.410	7717.1
¼	280.387	6256.1	¼	296.095	6976.7	¼	311.803	7736.6
⅜	280.780	6273.7	⅜	296.488	6995.3	⅜	312.196	7756.1
½	281.173	6291.2	½	296.881	7013.8	½	312.588	7775.6
⅝	281.565	6308.8	⅝	297.273	7032.4	⅝	312.981	7795.2
¾	281.958	6326.4	¾	297.666	7051.0	¾	313.374	7814.8
⅞	282.351	6344.1	⅞	298.059	7069.6	⅞	313.767	7834.4
90.	282.743	6361.7	**95.**	298.451	7088.2	**100.**	314.159	7854.0
⅛	283.136	6379.4	⅛	298.844	7106.9			

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APPENDIX

COVERING REPRINT OF PREFACE FROM TAYLOR (G. R. S.) CATALOGUE NO. 1, INFORMATION REQUIRED FOR THE DRAWING UP OF INTERLOCKING ESTIMATES, AND A LIST OF G. R. S. ELECTRIC INTERLOCKING LEVERS INSTALLED

APPENDIX

REPRINT OF PREFACE

From Catalogue No. 1 (1902), *Taylor Signal Company, Buffalo, N. Y. Taylor Signal Company acquired by the General Railway Signal Company in* 1904.

IN the last few years there has been a phenomenal increase in tonnage hauled on American railways, necessitating the purchase of more and better engines and cars of larger capacity, equipped with the best safety devices. Enormous sums have been expended in taking out curves, cutting down grades, laying additional main tracks, putting in new sidings, and providing improved terminal facilities. But, notwithstanding all these improvements, many lines find it impossible to handle their business with sufficient dispatch to avoid congestion. This fact has led many progressive American railway managers to realize that if they are to secure the best and most economical returns from the great expenditures made for motive power, car equipment, and tracks, suitable means must be provided to enable their trains to move with a minimum of delays and a maximum of safety; and this can only be realized when train orders are supplanted by an up-to-date block system and hand operated switches by a modern system of interlocking.

The very highest development of the art of signaling has been reached in this country, but no American railway is nearly so thoroughly equipped with signaling as is the average English line.

This lack of signal equipment will be better comprehended after considering some simple statistics.

The first interlocking plant installed on the London and Northwestern Railway was put in service in 1859; fourteen years later, in 1873, there were in use on that line alone 13,000 levers. At the same date there was not a single interlocking plant in use in the United States, the first plant in this country having been installed in the year 1874 by Messrs. Toucy and Buchanan at Spuyten Duyvil Junction, in New York City.

At the present time (1902) there are in use on the 1,800 miles of line of the London and Northwestern Railway approximately 36,000 interlocked levers, or an average of about twenty levers per mile of line, whereas there are only about 40,000 in use on all lines of the United States, or, approximately, one lever to five miles of line, or about 1 per cent. of the number of levers per mile used on the London and Northwestern Railway.

When it is remembered that probably more than one-half of the interlocked levers in use in this country are at grade crossings, leaving fewer than 20,000 levers used for station, yard and terminal work, whereas practically the entire 36,000 on the L. & N. W. are used for such work alone, it will be recognized that American railways are in general very poorly provided with modern signal appliances. In fact, there is probably to-day not a single American railway that is nearly so thoroughly equipped as the London and Northwestern was twenty-seven years ago, though, as might be expected, the devices in use on American lines having properly organized signal departments, capable of making suitable specifications, compare favorably with the best in use on European lines and, in numerous instances, large power plants are in use which are superior to anything ever devised abroad.

There can be no question as to the inability of most of our railways to move their trains with proper safety and dispatch during times when traffic is heavy; no competent railway operating officer doubts that proper systems of signaling would greatly aid in the safer and more rapid movement of trains and, while there are probably few American railway men who recognize fully how very far behind the best European lines our lines are in respect to the completeness of their signal equipment, this is becoming better understood every year and there is reason to believe that our most progressive lines will not much longer continue to limit the applications of interlocking to the protection of grade crossings with here and there a junction or yard plant.

Such being the case, it is probable that more signaling will be done in the near future than has ever before been done in this country and American railway managers will, therefore, find it greatly to their advantage to give serious consideration to the determination of what system of interlocking they can best use.

The earliest system employed and that in most general use at this time is the so-called "mechanical interlocking" in which the switches or signals are manually worked by means of interlocked levers connected with them by pipe or wire lines.

When properly installed, this system has given satisfactory results; but, unfortunately, in the effort of railway men to secure cheap appliances and in the stress of competition between the various manufacturers of signaling devices, a great many of the installations made in this country are very imperfect and unsafe.

Experience has shown that, in order to secure a reasonable degree of safety, it is absolutely essential that the following requirements be met:

All derails, movable point frogs, locks, switches and home signals should be worked by pipe; no signal should be worked by a single wire; all pipe and wire lines should be automatically compensated; all derails, movable point frogs and facing point switches should be provided with duplex facing point locks; all cranks and pipe compensators should be fixed on strong foundations set in best quality concrete; no facing point switch more than 600 feet from the tower should be taken into the system; no lever should be overloaded by putting on it such a number of switches and bars as to prevent a man of average strength from throwing it with one hand.

Where these and other proper specifications have been followed, fair results have been obtained, though it has long been recognized by American railway operating officials that this system has inherent defects that render it, under certain conditions, unsafe. For example, in the event of the breakage of a pipe or wire operating a signal, there can be no absolute assurance that such breakage will be known by the leverman or that such signal will occupy a position corresponding with that of its lever or that it will not indicate "line clear" when, its lever being normal, another and opposing signal is set at "line clear."

The fatigue incident to working mechanical levers is very great, so that it is frequently necessary to employ three eight-hour levermen for a comparatively small plant where the number of lever movements is considerable; if the plant is very large, it is sometimes necessary to employ as many as eight men on each of three shifts.

Moreover, under certain conditions it is very costly to operate such a system. For example, in cases where the distance between the extreme switches to be operated is over 1,600 feet, it is generally necessary to provide two mechanical interlocking towers, each with its own set of levermen, as it is neither safe nor practicable to work such switches from one tower. It is interesting to note in this connection that under the English Board of Trade requirements, which are wisely drawn and rigidly enforced, no facing point switch may be operated at a distance exceeding 540 feet from the tower. Even at this distance it is considered that ordinary pipe lines are not sufficiently strong or safe and many English lines now employ a steel channel section, cut to eighteen foot lengths and jointed by means of fish plates secured by six one-half inch bolts, this construction admitting of ready detection of rods weakened by corrosion and of their easy removal.

In order to overcome these and other disadvantages inherent in systems of mechanical interlocking, the "pneumatic system" was devised by Mr. George Westinghouse, Jr., the first working installation having been made at the crossing of the P. and R. and L. V. Railways, near Bound Brook, N. J., in 1884.

At the present time two varieties of this system are in use, one, popularly known as the "electro-pneumatic," in which air compressed to a working pressure of about sixty pounds is employed for moving switches and signals and in which the release locking is effected by electro-magnetic means; and the other, popularly known as the "low pressure pneumatic," in which air at a pressure of about twenty pounds is used for operation and in which compressed air effects the release locking.

Some of the advantages claimed for this system are as follows:

The ability to operate switches and signals at any desired distance from the cabin; that switches are actually required to be moved and securely locked in the proper position before a signal governing traffic over them can be cleared; that each signal, when cleared, automatically locks the lever operating it in such manner as to prevent the release of levers controlling conflicting signals and switches, until such signal has been again placed completely at danger, thus effectually providing against the simultaneous display of two conflicting clear signals; that, there being no moving parts between cabin and switches and signals, wear of mechanism, lost motion and the troublesome and dangerous effects of expansion and contraction of mechanically operated pipes and wires are all eliminated; that much less room is required for leadout connections than in a mechanical plant and much valuable space is thereby saved; that cabins of much smaller and lighter design are used; that the operation of the machine requires so little physical exertion that one man can do the work that would in a mechanical plant require three or four.

There can be no doubt that both varieties of the pneumatic system are far better adapted for the working of large plants than the mechanical as both largely fulfill the claims above referred to.

It is, however, found that in the electro-pneumatic system a cross between the release locking (commonly known as "indication") wire and the common return wire (or ground), will have the same effect as would the closing of the indication circuit in the proper manner, thus giving a false indication, which in view of the fact that the safety of any power interlocking depends upon the reliability of its indications, is highly objectionable. It is also found that where the indication is given by means of compressed air the release locking is often effected very slowly in cases where switches or signals are located at a considerable distance from the tower and this, at a busy plant, is also very objectionable.

Another disadvantage of the low pressure pneumatic system is that if a switch, meeting any obstruction, fails to complete its movement and to give indication, it is necessary either for a repairman to go immediately to the switch and operate it by hand or for the leverman to force the indication, which is often done and is evidently dangerous. Thus, in one style of the pneumatic system there is the defect due to possibility of false indication and in the other the defect due to slow indication and to inability to reverse a switch which has not fully completed its movement. Some other disadvantages of the pneumatic systems are as follows:

Liability to freezing of pipes and valves in extreme cold weather; high cost of furnishing power; danger of throwing near switches under trains when, owing to extreme cold weather, it is necessary to maintain higher than normal pressures in order to be able to work switches farthest from tower; high cost of maintenance owing to rapid deterioration of iron pipe lines placed underground and subjected to action of various salts and alkalies found in soil and to electrolytic action from electric railway and lighting circuits; difficulty and cost of locating leaks and breaks in pipe lines under ground; extremely high cost of installing and operating medium sized and small plants or a small number of switches or signals located at a considerable distance from the tower in a large plant.

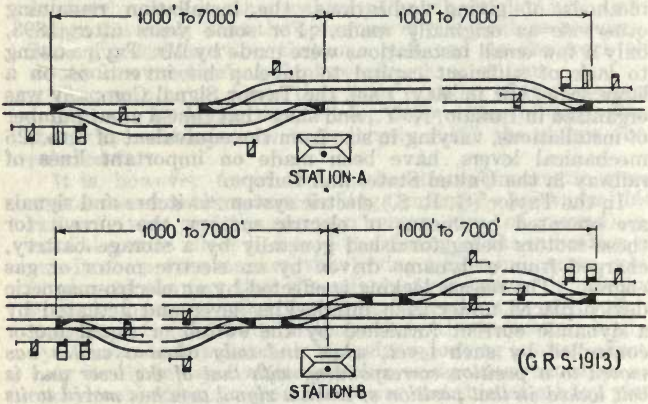
To overcome these and other objectionable features of the pneumatic system, the "electric" system was devised.

This system, the invention of Mr. John D. Taylor of Chillicothe, Ohio, was first installed by him on the B. & O. S. W. R'y at East Norwood, near Cincinnati, Ohio, in 1891; in 1893 certain improvements were introduced by him in the methods of giving indications, the installation remaining otherwise as originally made. For some years after 1893, only a few small installations were made by Mr. Taylor owing to lack of sufficient capital to develop his inventions on a large scale, but in May, 1900, the Taylor Signal Company was organized in Buffalo, N. Y., and since that time a great number of installations, varying in size from the equivalent of 6 to 225 mechanical levers, have been made on important lines of railway in the United States and Europe.

In the Taylor (G. R. S.) electric system, switches and signals are operated by means of electric motors, the current for these motors being furnished generally by a storage battery, charged from a dynamo driven by an electric motor or gas engine. The release locking is effected by an electro-magnetic device placed under each interlocking lever and actuated by a dynamic current furnished by the switch or signal motor controlled by such lever, *when and only when a switch has moved to a position corresponding with that of the lever and is bolt locked in that position or when a signal arm has moved to its full danger position.* Crosses between an indication wire and common return wire (or ground) or any other wire of the system, can at worst only prevent the giving of indication and cannot by any possibility result in the giving of a false clear indication as can occur in other systems employing electro-magnetic indications. Moreover, in this system, indications are given *instantaneously* upon completion of locking of switch or of movement of signal to its stop position, irrespective of the distance of such switch or signal from the tower, thus effecting a great saving in the time required by any system using pneumatic indications, to set up a route.

If, when a switch is thrown, it fails to complete its movement owing to some obstruction between point and stock rail, or for any cause whatever, the switch can be restored by the leverman to its original position and another effort can be made to perform the desired movement, ofttimes thus avoiding the necessity, so frequently met with in the low pressure pneumatic system, of sending a man out to throw the switch by hand or of forcing the indication.

The electric is the only power system that can be satisfactorily employed for the operation of plants having a small number of switches and signals. It is in service where as few as six working levers are employed and is perfectly adapted for use at all junctions, crossings, drawbridges, tunnels, stations, yards, passing sidings, etc., where the distance between extreme switches or signals is greater than can be safely covered with a mechanical plant, even though there be only a very few signals and switches to be operated. For example, consider the two following diagrams, the first one showing arrangement of passing sidings on a single track and the other on a double track line:



On a few of the best signaled American railways the switches and signals immediately adjacent to the station A or B, would be worked by a mechanical interlocking plant, but owing to the great cost of operating an additional mechanical interlocking plant at each of the extreme switches and the prohibitive cost of putting in a pneumatic power system by which all the switches and signals could be worked from the station, the inlet switches are left to be worked by the trainmen, necessitating the stopping of their trains; and if, as sometimes happens, such stoppage occurs on a bad grade, heavy trains may break in two in starting up. Every practical railway man will at once recognize the tremendous advantage that would be gained if these extreme switches, together with their proper signals, could be safely and economically worked from the station, thereby enabling trains to pass onto and out of passing sidings at speed and in absolute safety. With the Taylor (G. R. S.) electric system this can be effected at a relatively small cost, and, in conjunction with a system of automatic, electric, track circuit block signals in use on the open road, where there are no switches, this forms the ideal lock and block system and one, which we believe is destined to replace all others both in this country and in Europe.

In the electric system, the cost of producing power for the operation of switches and signals rarely or never exceeds 1 per cent. of the cost in any other power system doing an equal amount of work. For example, if in a system using compressed air, the cost of coal and services of men employed in running power plant is 400 dollars per month, the total cost of producing power for an electric plant doing precisely the same work will rarely or never exceed four dollars monthly.

In this connection it will be interesting to note that at the South Englewood Taylor (G. R. S.) interlocking plant on the C. R. I. & P. R. R., where the average daily number of switches moved and signals cleared is 2,250, the consumption of gasoline for running engine for charging storage batteries, was sixty-eight gallons in eighty-six days, or one gallon for 2,845 switch and signal operations. At Sixteenth and Clark streets, Chicago, Taylor (G. R. S.) interlocking plant at the crossing of the St. Charles Air Line with the C. R. I. & P. and L. S. & M. S. R'ys, where the movement exceeds 600 trains daily, the consumption of gasoline during 153 days was 222 gallons for 642,600 switch and signal movements or 2,894 per gallon or about 326 movements for one cent for power.

The cost of maintenance and renewals in an electric plant is only a small percentage of the cost in any other power plant. This can be readily understood from the fact that more feet of electrical conductors are employed in the electro-pneumatic system than are used in the Taylor (G. R. S.) system and there are all the pneumatic pipes; and, in the low pressure pneumatic system, more feet of iron pipe are used than feet of electric conductors in the Taylor (G. R. S.) system, and any one having experience with the rapid deterioration of iron pipes placed in the soils found about railways and subject to electrolysis, will have no difficulty in understanding how much shorter lived these underground pipes will be than well insulated copper wires placed in a suitable conduit above ground. Nor is it hard to understand how much more difficult and costly it will be to make repairs to such pipe placed several feet underground than it will be to repair a break or leak in a wire placed in a suitable conduit above ground.

In this connection, it is interesting to note that the B. & O. S. W. R. R., which was the first to install the Taylor (G. R. S.) system, has found it far cheaper to maintain than an ordinary mechanical plant, and this is particularly true where, through change in grade or alignment of tracks, any changes are required in the interlocking plant, such changes being many times more costly in any other system than in the Taylor (G. R. S.) electric. Moreover, with the improved devices and methods of installation now used in this system, a far better showing will be made.

The operation of the electric system is absolutely unaffected by change in temperature, whereas pneumatic systems sometimes experience serious difficulties owing to condensation and freezing of moisture contained in the compressed air, by which the mechanism becomes clogged and its working prevented.

Even where the working is not absolutely prevented under these conditions, it frequently becomes necessary to raise the pressure so high in order to compensate for losses in pressure at distant switches, that there is danger of throwing near switches under train, in case leverman makes an improper movement at such a time, as it is certain that as generally installed, detector bar connections are not sufficiently strong to resist any considerable increase above the normal working pressure in a pneumatic plant. It is therefore doubtful whether, during extreme cold weather, it is ever safe to attempt to work from one pneumatic machine, switches and signal, located so far from the tower as to require any increase over normal working pressure. Unquestionably, the safer practice, at such times, is to temporarily abandon the working of such switches and signals, as is often done, though this, of course, causes much troublesome delay and expense.

In the electric system no such condition exists, as the "electric pressure" is exactly the same on the switch or signal motor located at a distance of 5,000 feet as on one located 500 feet from the tower; moreover, the system is so arranged that the throwing of a switch lever while train is over the switch would cause the blowing of a fuse on the machine, thereby opening the circuit.

In the foregoing statement no effort has been made to describe in detail the appliances and circuits employed in the Taylor (G. R. S.) electric system of interlocking; our object has been solely to point out the need of signal equipment on American railways and to state, without prejudice, the principal merits and defects of the several interlocking systems at present employed, in order to aid such railway officials as have not had opportunity to acquaint themselves with the facts above set forth to make an intelligent comparison between such systems.

The Taylor (G. R. S.) electric system is in the fullest accord with modern engineering practice which has shown, after years of experiment, that transmission of power to a distance can be more satisfactorily accomplished by means of electricity than by any other agency and, while there is no reason to doubt that this system will be improved in the future as in the past, we feel warranted in claiming at the present time that it represents the very highest development of the art of signaling, embodying features of safety, economy and general applicability not possessed by any other system in use in this country or abroad.

TAYLOR SIGNAL COMPANY.
(GENERAL RAILWAY SIGNAL COMPANY.)

INFORMATION TO BE FURNISHED BY THE RAILWAY COMPANY WHEN REQUESTING AN ESTIMATE ON ELECTRIC INTERLOCKING

In order to prepare promptly an accurate estimate on a proposed installation of electric interlocking, it is necessary that definite information on certain items be furnished by the Railway Company with the request for a proposal. This information can best be covered by a specification together with certain plans.

It is not necessary for each individual railroad to prepare a specification form as the Railway Signal Association adopted, in 1910, a very complete specification covering this practice. The specification has been prepared by a committee of men, actively engaged in railway signal work, and its use is heartily recommended. It can be secured by reference to the Manual of the Railway Signal Association issued in 1912. It has, of course, been necessary in drawing up this specification to leave optional a number of items, definite information on which should be given with each request for an estimate. Attention is especially directed to certain points essential to the preparation of estimates, covered by sections of the specification as follows:

3. "*Drawings.*"

A track plan should be furnished giving very completely the information under sub-paragraph 1. The symbols which have been adopted by the Railway Signal Association as shown on pages 348 to 359 of this Handbook should be used. The information called for in sub-paragraphs 2, 3 and 4 should be given if possible, although this is not absolutely necessary.

7. "*Materials to be furnished and work to be done by and at the expense of the Purchaser.*"

Consideration should be given to the items listed in this paragraph and note made of any deviation therefrom.

18. "*Transportation.*"

A definite statement should be made as to whether transportation is to be furnished for men, tools and materials or for either.

50. "*Building foundations.*"
51. "*Interlocking station.*"
52. "*Power house.*"
It should be clearly stated whether the contractor is to erect the buildings and their foundations, the dimensions and specifications being given if such is the case.

54. "*Lighting for buildings.*"
When electric lighting for any of the buildings is desired, paragraphs a, b, c and d should be filled out.

60. "*Plant.*" (*Power Plant.*)
61. "*Engine.*"
70. "*Motor.*"
85. "*Storage battery.*"
Definite information must be given as to the power supply. The ampere hour capacity and number of cells of the battery should be specified as well as the capacity of any charging apparatus desired. Data on pages 154 to 159 of this Handbook will be of assistance in determining the proper capacities for the battery and charging apparatus.

100. "*Machine.*" (*Interlocking Machine.*)
While a properly prepared track plan will determine the size and arrangement of levers in the interlocking machine, it will be necessary to specify any spare spaces or spare levers required in the event of this information not being shown on the plan.

502. "*Track circuits.*"
The number and arrangement of track circuits to be installed should be shown on the plans or covered in the specification.

506. "*Electric lighting circuits.*"
The information called for in this section should be given, attention being called to pages 127 to 130 in this Handbook.

510. "*Special circuits.*"
Typical plans of special circuits may be furnished under this section or the circuit requirements stated, in which event the contractor will submit typical proposed circuits with the estimate. Pages 133 to 139 of this Handbook are devoted to Electric Locking circuits, the data being based on the R. S. A. classification of the different types of circuits.

521. "*Size.*" (*Wire and Wiring.*)
The data as to size of wires under paragraph " f " should be given when track circuits are to be installed.

ELECTRIC INTERLOCKING LEVERS INSTALLED AND UNDER CONTRACT

JANUARY 1, 1913

Name of Road	Number of Plants	Total Levers
Atchinson, Topeka & Santa Fé R'y,	40	1348
Atlanta, Birmingham & Atlantic R'y,	1	48
Atlanta Terminal Station,	2	184
Baltimore & Ohio,	19	880
Birmingham Terminal Station,	1	144
Buffalo Creek R. R.,	1	84
Canadian Pacific R'y,	3	40
Central of Georgia R'y,	1	52
Central R. R. of New Jersey,	1	28
Chattanooga Union Station Co.,	1	120
Chesapeake & Ohio R'y,	7	212
Chicago & Alton R. R.,	2	108
Chicago & Eastern Illinois R. R.,	4	136
Chicago & Milwaukee Electric,	1	32
Chicago & Northwestern R'y,	35	2100
Chicago & Western Indiana R. R.,	1	24
Chicago, Burlington & Quincy R. R.,	7	464
Chicago Great Western R. R.,	5	128
Chicago, Indianapolis & Louisville R'y (Monon),	1	28
Chicago, Milwaukee & St. Paul R'y,	10	416
Chicago, Rock Island & Pacific R'y,	5	494
Chicago, St. Paul, Minneapolis & Omaha R'y,	5	80
Cincinnati, New Orleans & Texas Pacific R'y,	6	208
Cleveland, Cincinnati, Chicago & St. Louis R'y,	13	556
Copper Range R. R.,	1	40
Cumberland Valley R. R.,	3	24
Delaware & Hudson Co.,	2	64
Department of Public Works, British Columbia,	1	28
Detroit & Toledo Construction Co.,	1	32
Detroit River Tunnel Co.,	4	264
Elgin, Joliet & Eastern R'y,	2	72
Erie R. R.,	11	614
Galveston, Harrisburg & San Antonio R'y,	1	40
Grand Trunk R'y,	2	60
Great Northern R'y,	6	200
Gulf, Colorado & Santa Fé R'y,	1	48
Houston & Texas Central R. R.,	8	248
Houston Belt & Terminal R'y,	3	140
Hudson & Manhattan R. R.,	10	128
Illinois Central R. R.,	20	824
Kansas City Terminal R'y,	1	56
Kentucky & Indiana Terminal R. R.,	1	56
Lake Shore & Michigan Southern R'y,	28	1778
Lehigh Valley R. R.,	9	384
Long Island R. R.,	2	68
Louisville & Nashville R. R.,	4	160

Name of Road	Number of Plants	Total Levers
Louisiana R'y & Navigation Co., ...	1	28
Michigan Central R. R., ...	6	272
Missouri Pacific R'y, ...	1	32
Morgan's Louisiana & Texas R. R. & S. S. Co., .	1	32
Nashville, Chattanooga & St. Louis R'y, ...	1	140
New York Central & Hudson River R. R., . . .	32	2744
New York, New Haven & Hartford R. R., ...	3	96
Norfolk & Western R'y, ...	1	56
Northern Pacific R'y, ...	7	140
Northwestern Elevated R. R., ...	1	28
Oregon Short Line, ...	1	52
Oregon, Washington R. R. & Navigation Co., . .	2	152
Pacific Electric R'y, ...	4	164
Pecos & North Texas Ry., ...	1	28
Pennsylvania Lines West of Pittsburgh, ...	16	952
Pennsylvania R. R., ...	3	72
Peoria & Pekin Union R'y, ...	1	56
Pere Marquette R. R., ...	6	248
Pittsburgh & Lake Erie R. R., ...	4	260
Railway Signal Co., of Canada (Grand Trunk R'y),	1	72
San Francisco-Oakland Terminal R'y, ...	2	76
Savannah Union Station, ...	2	68
Southern Indiana R'y, ...	1	32
Southern Pacific Co., ...	17	664
Southern Railway, ...	1	20
Spokane & Inland Empire R. R., ...	1	16
Terminal R. R. Assn. of St. Louis, ...	6	484
Texas & Pacific R'y, ...	1	120
Tidewater & Western R. R., ...	1	40
Toledo & Ohio Central R. R., ...	2	128
Toledo R'y & Light Co., ...	1	4
Toledo R'y & Terminal Co., ...	2	68
Toronto, Hamilton & Buffalo R'y, ...	1	88
Union Pacific R. R., ...	6	380
Washington, Baltimore & Annapolis Electric R'y,	1	44
Western Pacific R'y, ...	6	180
Wisconsin Central R. R., ...	3	92
Grand Total, ...	440	21,370

INDEX

Name of Road	Number of Plants	[illegible]
Louisiana R'y & Navigation Co.	[illegible]	[illegible]
Michigan Central R. R.	[illegible]	[illegible]
Missouri Pacific R'y.	[illegible]	[illegible]
Morgan's Louisiana & Texas R. R. & S. S. Co.	[illegible]	[illegible]
Nashville, Chattanooga & St. Louis R'y.	[illegible]	[illegible]
New York Central & Hudson River R. R.	[illegible]	[illegible]
New York, New Haven & Hartford R. R.	[illegible]	[illegible]
Norfolk & Western R'y.	[illegible]	[illegible]
Northern Pacific R'y.	[illegible]	[illegible]
Northwestern Elevated R. R.	[illegible]	[illegible]
Oregon Short Line	[illegible]	[illegible]
Oregon, Washington R. R. & Navigation Co.	[illegible]	[illegible]
Pacific Electric R'y.	[illegible]	[illegible]
Pecos & North Texas R'y.	[illegible]	[illegible]
Pennsylvania Lines West of Pittsburgh.	16	[illegible]
Pennsylvania R. R.	[illegible]	[illegible]
Peoria & Pekin Union R'y.	[illegible]	[illegible]
Pere Marquette R. R.	[illegible]	[illegible]
Pittsburgh & Lake Erie R. R.	[illegible]	[illegible]
Railway Signal Co. of Canada (Grand Trunk R'y.)	[illegible]	[illegible]
San Francisco-Oakland Terminal R'y.	[illegible]	[illegible]
Savannah Union Station.	[illegible]	[illegible]
Southern Indiana R'y.	[illegible]	[illegible]
Southern Pacific Co.	[illegible]	[illegible]
Southern Railway.	[illegible]	[illegible]
Spokane & Inland Empire R. R.	[illegible]	[illegible]
Terminal R. R. Ass'n of St. Louis.	[illegible]	[illegible]
Texas & Pacific R'y.	[illegible]	[illegible]
Tidewater & Western R. R.	[illegible]	[illegible]
Toledo & Ohio Central R. R.	[illegible]	[illegible]
Toledo R'ys & Light Co.	[illegible]	[illegible]
Toledo R'y & Terminal Co.	[illegible]	[illegible]
Toronto, Hamilton & Buffalo R'y.	[illegible]	[illegible]
Union Pacific R. R.	[illegible]	[illegible]
Washington, Baltimore & Annapolis Electric R'y.	[illegible]	[illegible]
Western Pacific R'y.	[illegible]	[illegible]
Wisconsin Central R. R.	[illegible]	[illegible]
Grand Total	440	[illegible]

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