American Railway Signaling Principles and Practices

CHAPTER XXIV

Signal Power Transmission and Lightning Protection

Published by the Signal Section, AAR
59 East Van Buren Street, Chicago 5, Ill.

REVISED MARCH 1959

CONTENTS

American Railway Signaling Principles and Practices

CHAPTER XXIV

Signal Power Transmission and Lightning Protection

REVISED MARCH 1959

Published By
Association of American Railroads, Signal Section
59 East Van Buren Street, Chicago 5, Ill.

CHAPTER XXIV

Signal Power Transmission and Lightning Protection

SIGNAL POWER TRANSMISSION

General.

Power transmission systems for signal purposes have been designed for alternating current voltages commercially available. Various voltages are utilized for what are commonly known as charging lines, which furnish power for charging storage batteries, which in turn operate track circuits or signals, as well as furnish power for signal lighting.

Higher voltages are used where load and distances are great, where commercial power is not readily available, or where most of the signal apparatus is operated from alternating current. The voltages used in such systems are 2400, 4800 and 7200 volts at 25, 60 or 100-cycle frequency. A frequency of 60 cycles is generally used for alternating current railway signaling; but on railroads using direct current propulsion, where 25-cycle power is supplied to rotary converters or to rectifiers for supplying the direct current propulsion power, the 25-cycle power may also be used for railway signaling purposes. A frequency of 100 cycles is sometimes used in the installation of cab signal and train control systems to avoid interference from commercial sources of 60-cycle power.

A special frequency of 91⅔ cycles is used for signal purposes on an electrified railroad system where joint d.c.-a.c. propulsion operation is being used since it developed that, due to the d.c.-a.c. rail return circuits being tied together at the substation, a fourth harmonic of the 25-cycle propulsion current resulted, creating an interference with the operation of the 100-cycle cab signal equipment.

The signal power supply is usually obtained from a commercial source. However, some railroads have installed their own generating equipment. The power supply may be either single-phase or three-phase.

Construction—open line.

Signal power transmission lines built for voltages of 480 volts or less are usually placed on the cross-arms of existing communication pole lines, the usual practice being to assign two pins of a cross-arm to this circuit, using a distinctive insulator or other means to identify the circuit. In some cases, the signal transmission line is supported by a cross-arm located above the communication lines and near the top of the pole, or may utilize a specially designed bracket. This latter design is generally used for voltages above 480 volts.

Figure 1 illustrates a typical communication line with a signal transmission line near the top of the pole for voltages generally above 480.

Signal power transmission lines above 600 volts are usually on a separate pole line on the opposite side of the track from the communication line. In some cases, the signal line control circuits are placed on a separate arm of the same pole line under the signal power transmission lines. On railroads using

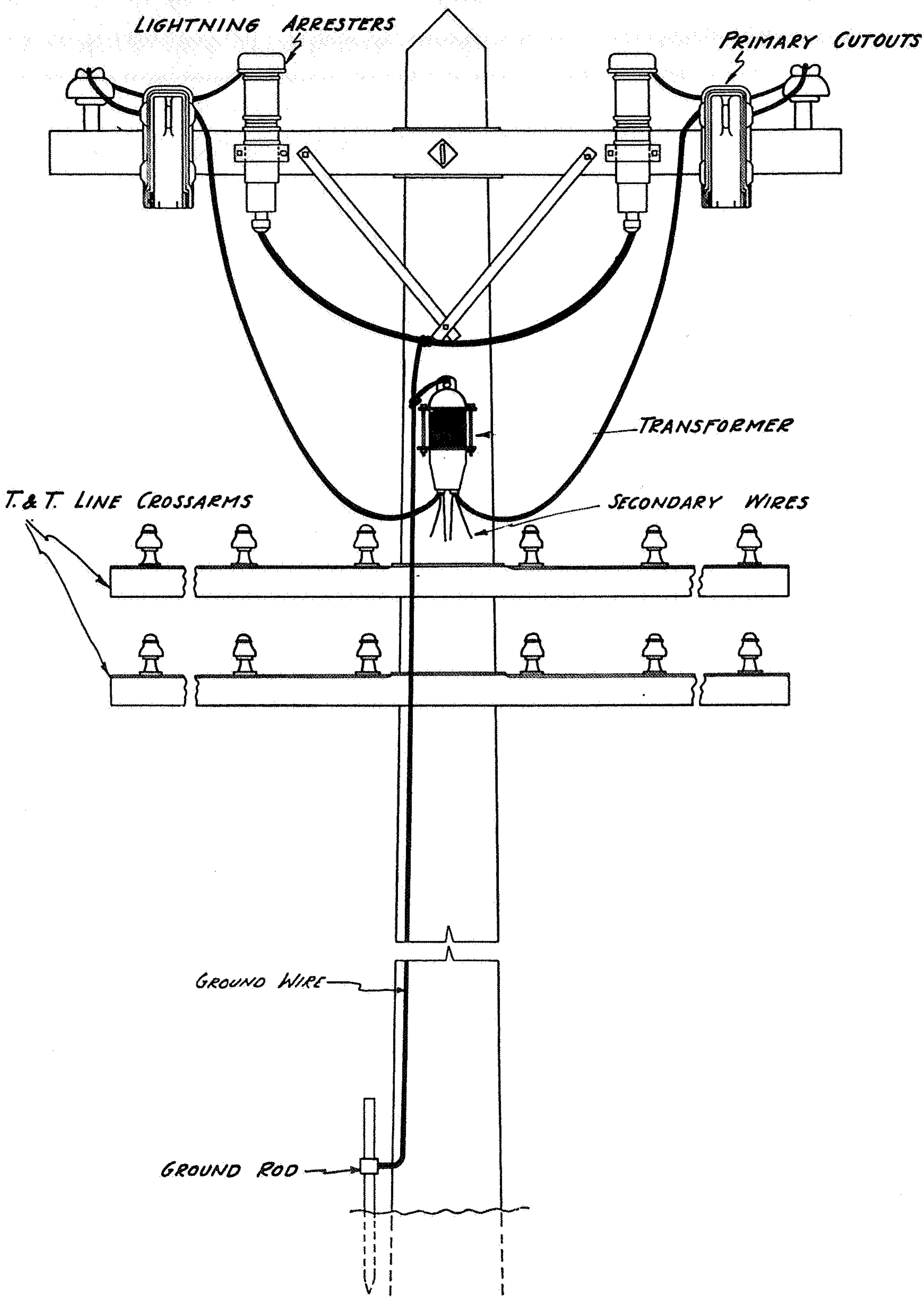
LIGHTNING ARRESTERS
PRIMARY CUTOUTS
TRANSFORMER
T. & T. LINE CROSSARMS
SECONDARY WIRES
GROUND WIRE
GROUND ROD

Fig. 1.

a catenary-supported trolley wire, the signal power transmission line is generally attached to the structure supporting the catenary system. The signal power transmission line is installed above the catenary system fastenings and below the propulsion power transmission wires which are usually supported near the top of the catenary pole structures.

Figure 2 illustrates a typical signal power transmission line mounted on catenary poles.

Because of the proximity of other wires and to provide some protection against possible damage to communication equipment, the conductors of the signal power transmission lines located on cross-arms of communication lines usually have a weatherproof covering. The weatherproof covering must not be depended on for safety in handling.

When signal power transmission lines are constructed on a separate pole line or on catenary-supporting structures, bare wire is generally used. Ordinarily, solid copper wire is used in constructing signal power transmission lines. However, in some cases stranded copper wire or stranded aluminum wire with a steel center is used. The size and composition of the conductor should be sufficient to have the necessary mechanical strength for the length of span and physical loading specified for the particular locality and to limit the voltage drop to less than 10 per cent where possible. On signal power transmission lines of 480 volts and under, voltage drop allowances have been made for as high as 20 per cent where distances between commercial power sources are too great to obtain a smaller voltage drop without going to excessive cost for heavier conductors. Voltage drops greater than 10 per cent should be avoided when practical, to provide sufficient voltage for proper operation of signal apparatus.

Construction—underground lines.

There are in service high voltage signal power transmission lines installed in ducts or conduit underground, where the usual practice is to install lead-sheathed or non-metallic sheathed cables with transformer and sectionalizing switches located in manholes or in metal sectionalizing cases provided with primary fused cut-outs and mounted on suitable foundations. The oil switch and transformer in sectionalizing case are installed as illustrated in Fig. 3. In the circuit between the oil switch and the transformer, cut-outs are usually installed so that the transformer may be isolated from the oil switch when required.

In underground installations, lightning arresters are not used at transformer locations as experience has shown the soil usually provides adequate shielding for the lines. Other installations of signal power transmission lines have been made where lead-covered cable is suspended on existing communication poles. In this type of construction, sectionalizing locations may be installed similar to that shown in Fig. 3.

Signal power transmission lines have been constructed which use open line wires for one portion of the line and cable for the remaining portion. The transformer locations and protection in this type of construction are similar to that explained for suspended lead-covered cable, except additional lightning protection is provided at the location where cable construction changes to open line construction. Figure 4 illustrates this method of construction.

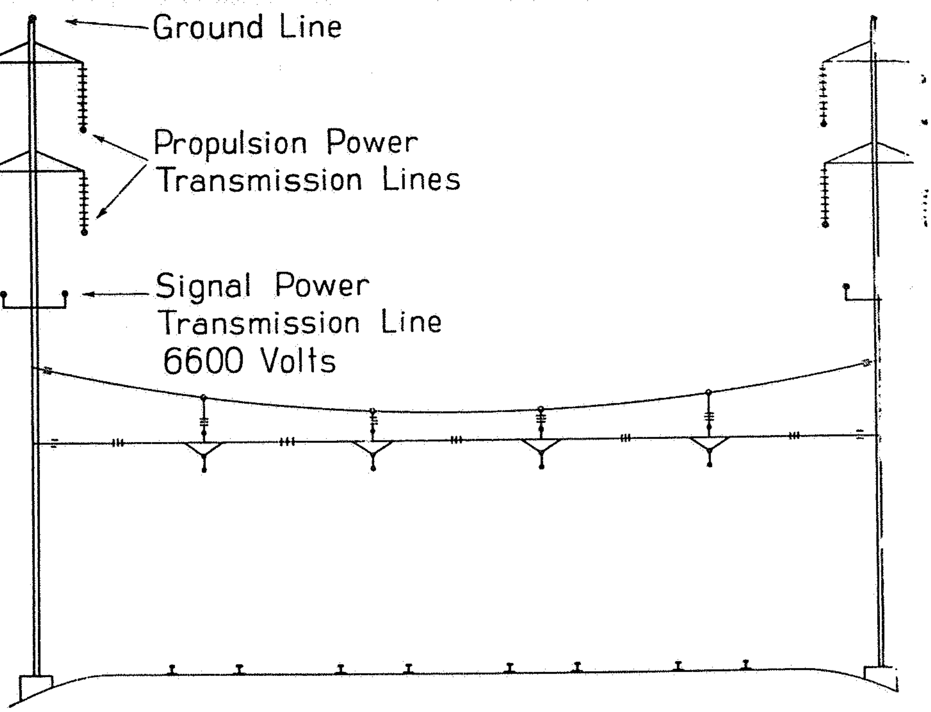
Ground Line
Propulsion Power
Transmission Lines
Signal Power
Transmission Line
6600 Volts

Fig. 2.

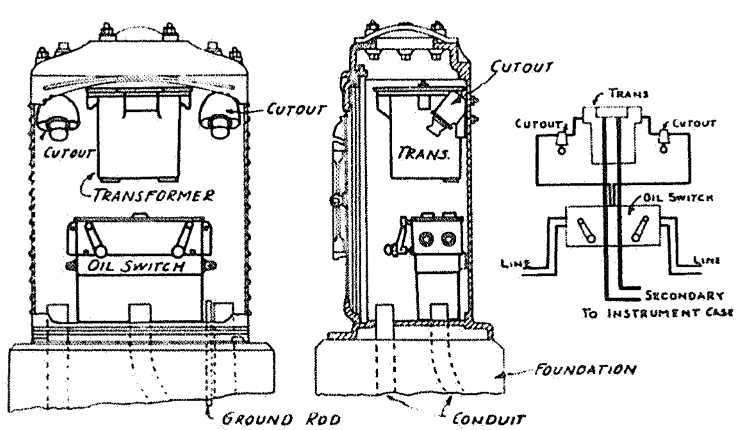
CUTOUT
CUTOUT
TRANSFORMER
OIL SWITCH
CUTOUT
TRANS.
TRANS
CUTOUT
CUTOUT
OIL SWITCH
LINE
LINE
SECONDARY
TO INSTRUMENT CASE
FOUNDATION
GROUND ROD
CONDUIT

Fig. 3.

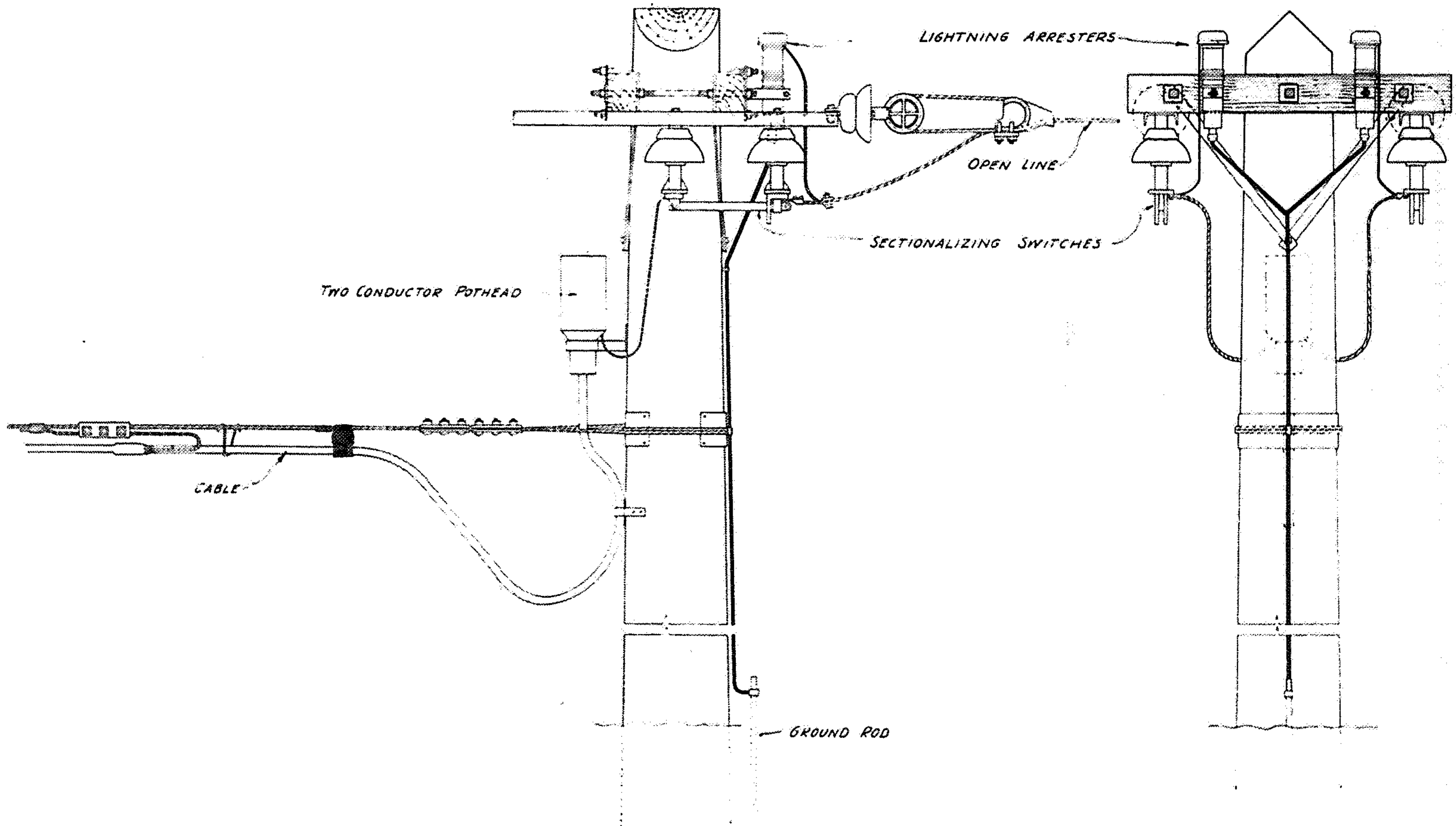

Fig. 4.
Sectionalizing Arrangement Between Open Line and Cable.

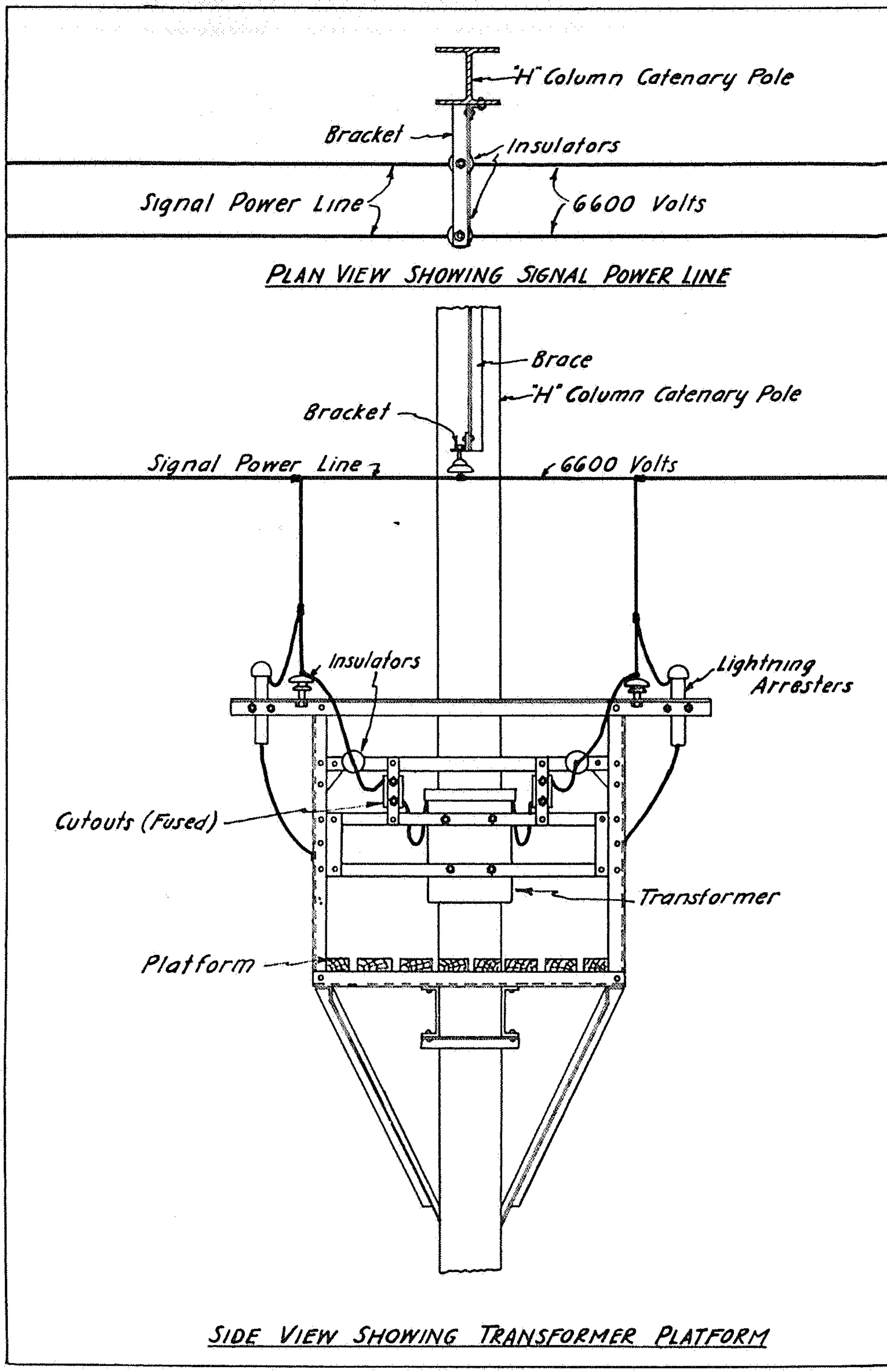

Fig. 5.
Sectionalizing Arrangement on Catenary Pole.

Transformer locations.

Transformers are installed at signal or cut-sections where a source of alternating current is required at a reduced voltage. On transmission systems where the primary voltage is not more than 600 volts, air-cooled transformers are commonly used except for heavier loads. For voltages over 600 volts, oil-cooled transformers are more practical. These transformers usually have a secondary voltage of 120 or 240 volts depending on voltage requirements of signal apparatus at the location. At transformer locations where the primary voltage is over 600 volts, the transformers and sectionalizing arrangements are provided in an assembly on the pole or catenary structure, the secondary circuits from the transformer being taken from the pole to the location in a manner standard with each railroad. A typical transformer installation on a catenary structure is illustrated in Fig. 5.

At transformer locations installed on distribution systems using 240 to 600 volts, a sectionalizing arrangement sometimes is provided on the pole as shown in Fig. 6, and at other locations sectionalization is provided in a case on the ground adjacent to pole as illustrated in Fig. 7.

Sectionalizing switches of various types have been used. In some installations, hook-operated knife switches mounted near the top of the pole have been installed. Figure 8 illustrates a transformer and sectionalizing arrangement where power is transmitted on a separate pole line. Other installations have been made with sectionalizing switches, so designed that they could be operated by means of a handle near the base of the pole. Where this type of switch is installed a suitable locking device is provided to prevent malicious interference. In some installations, it is the practice to sectionalize the power transmission line at each signal or cut-section. In others, sectionalizing is provided at points a considerable distance apart. Frequency of sectionalizing has much to do with economy of line construction and is one of the reasons why frequent sectionalizing is omitted. Frequent sectionalizing also increases the possibility of excessive voltage drop, due to resistance in switch blades, hinges, etc., although modern design of the switching equipment has reduced line loss from this source. On railroads where traffic is dense, frequent sectionalizing is required to minimize operating interference due to power outages.

Where sectionalizing is omitted at each individual transformer location, a tap is made on the transmission line and fused cut-outs are installed between the line and transformer. Cut-outs are usually provided with a mechanism which indicates a blown fuse. Some cut-outs are so designed that when one fuse melts, another stand-by fuse is automatically placed in the circuit, and at the same time a visual indication is displayed showing that the fuse has blown. Other types merely display the indication of a blown fuse by means of a vivid colored tube being displayed, while others in addition to displaying the color indication cause the door to drop to 180 degrees from its normal position. The color indications which are visible from the ground and door opening provision, are activated by spring loaded mechanism, which action is released when the fuse melts. Figures 9 and 10 illustrate a fused cut-out in the open and closed positions. Lightning arresters of the proper type and voltage rating are installed on the line at the pole. In addition, in some installations, lightning arresters have been provided on the two poles adjacent to each side of the transformer. In most cases it is the practice to ground the transformer case to the lightning arrester ground. Where the transformer assembly is mounted

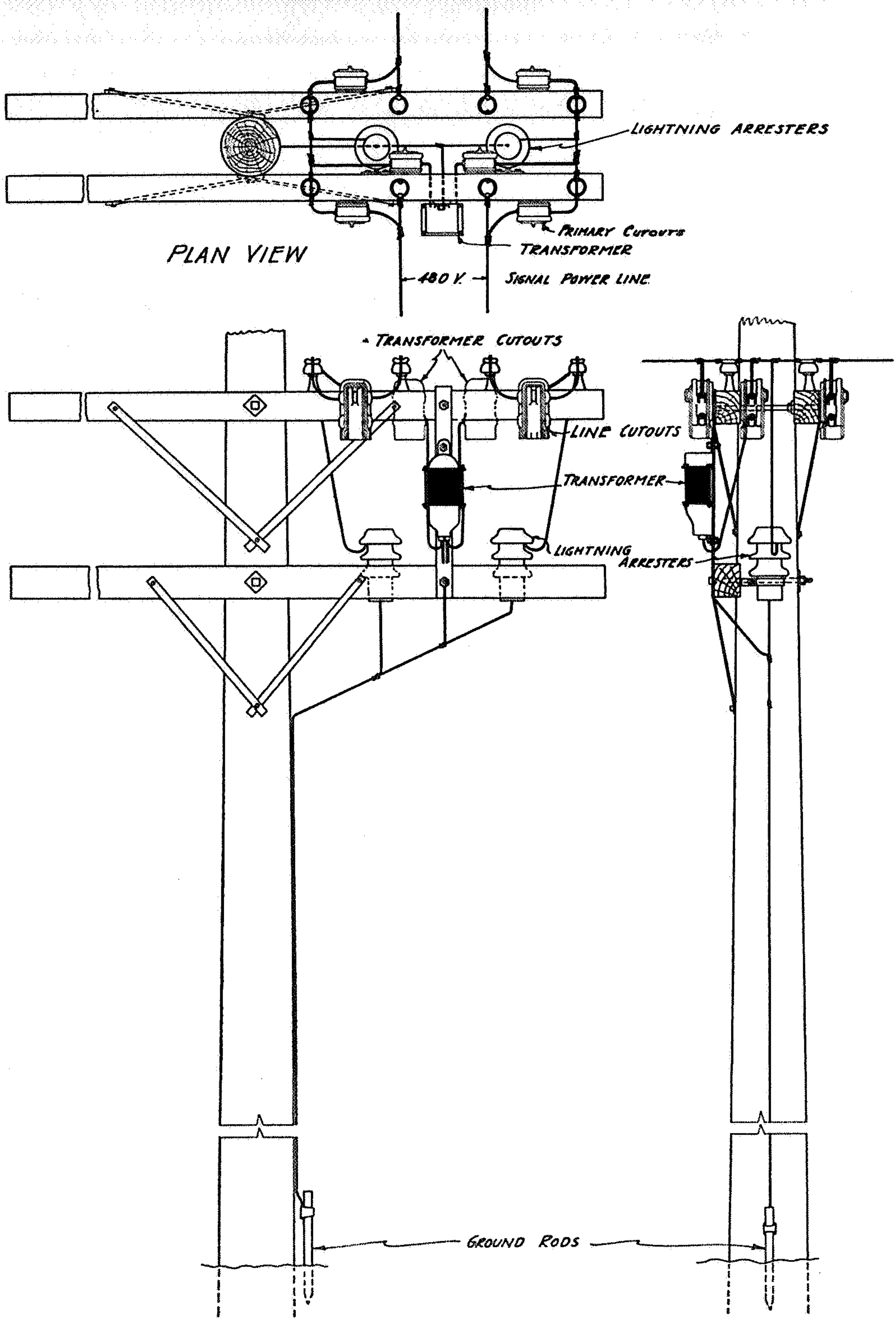
LIGHTNING ARRESTERS
PRIMARY CUTOUTS
TRANSFORMER
PLAN VIEW
480 V.
SIGNAL POWER LINE
TRANSFORMER CUTOUTS
LINE CUTOUTS
TRANSFORMER
LIGHTNING ARRESTERS
GROUND RODS

Fig. 6

on a catenary structure it is the usual practice to ground the arresters and transformer case to the structure itself. Various types of lightning arresters are used in signal power transmission lines and are described in this chapter under the heading, "Lightning Protection."

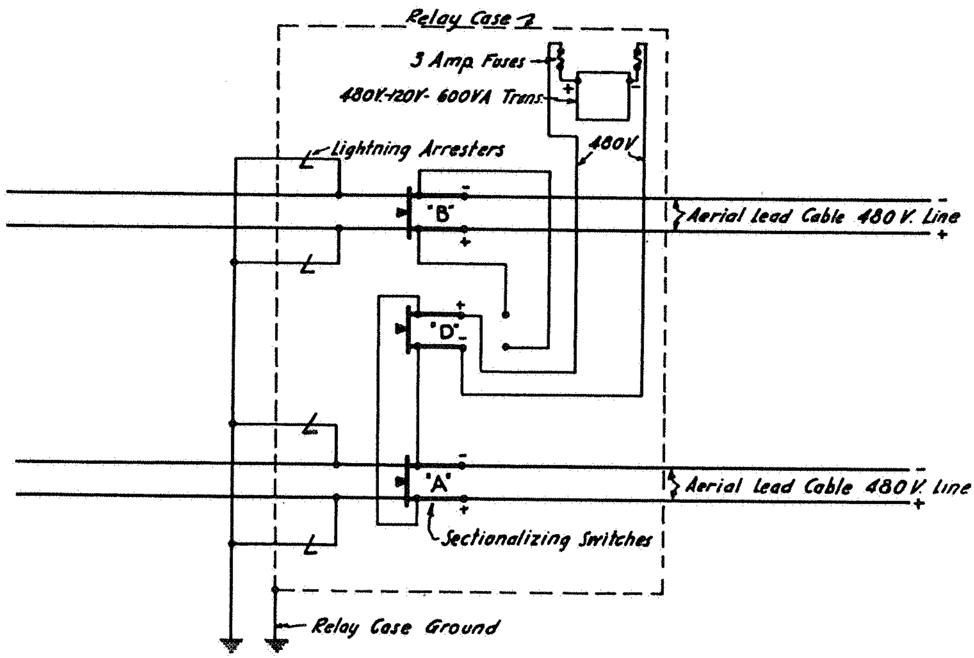

Fig. 7.

Through coordinated studies and research by commercial companies and railroads, transformers have been designed to meet the exacting requirements of the modern signal system. Detailed description and characteristics of the various transformers used in signal systems are given in Chapter VIII—Transformers.

The addition of an inductive load at a transformer location will cause the line current to be increased for a given amount of power transmitted. This results from the low power factor of the load, since the volt-amperes are greater for a given watts load. The increased line amperes would give greater line drop. Where this increase in line current is great enough to cause excessive line drop, a capacitor is added to the secondary side of the transformer to raise the power factor, thus reducing the line current required for the location. The capacitors are relatively small in size and are located in the instrument case. A fuse is connected in series with the capacitor so that in the event of a short circuit in the capacitor, the fuse will disconnect the capacitor from the circuit, allowing the signal system to remain in service.

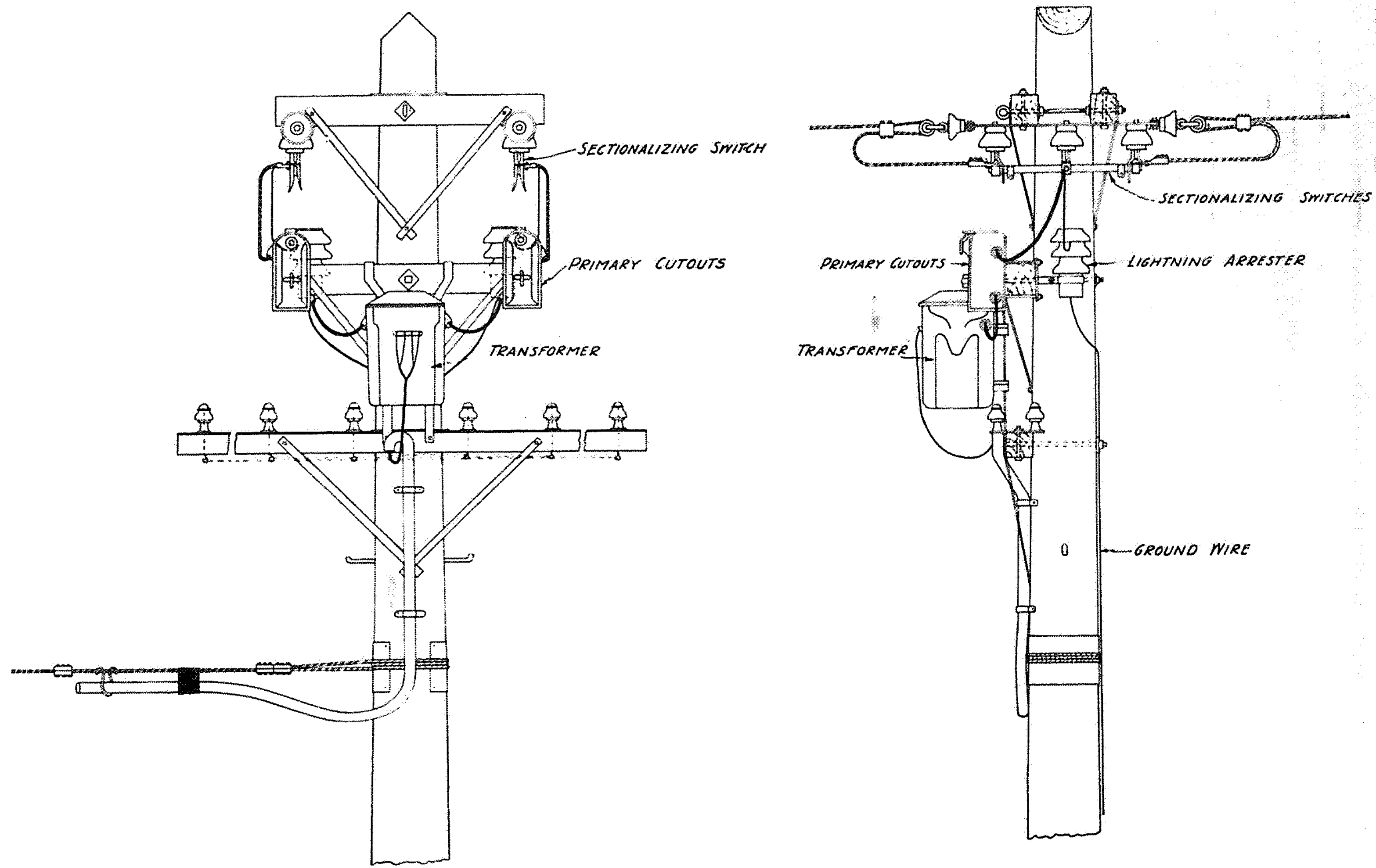
SECTIONALIZING SWITCH
PRIMARY CUTOUTS
TRANSFORMER
SECTIONALIZING SWITCHES
PRIMARY CUTOUTS
LIGHTNING ARRESTER
TRANSFORMER
GROUND WIRE

Fig. 8.

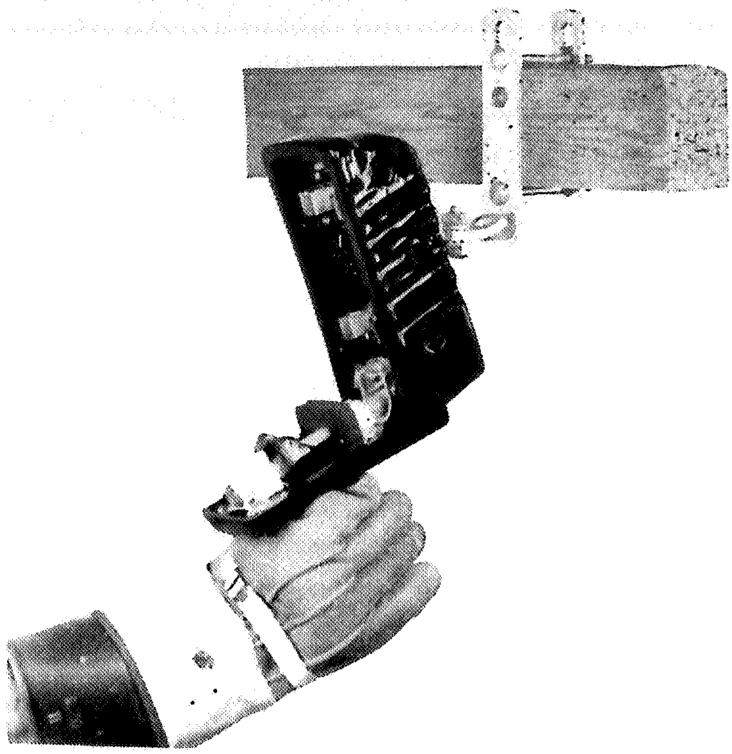

Fig. 9.
Cut-Out—Open.

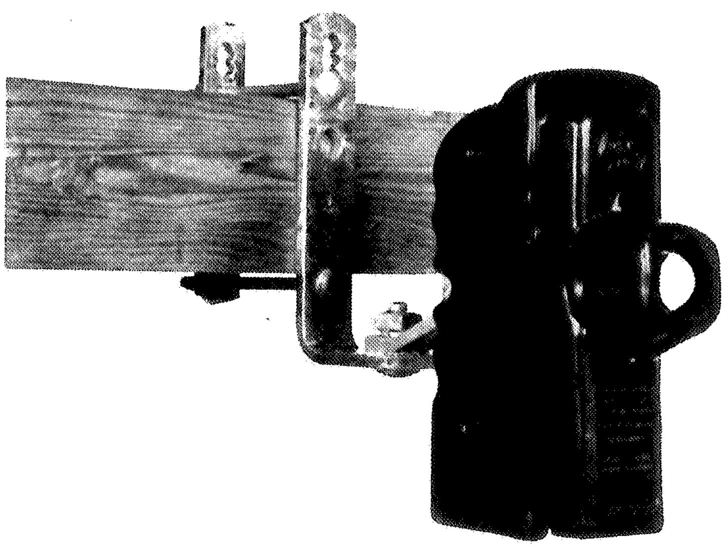

Fig. 10.
Cut-Out—Closed.

Figure 11 illustrates capacitors used for this purpose.

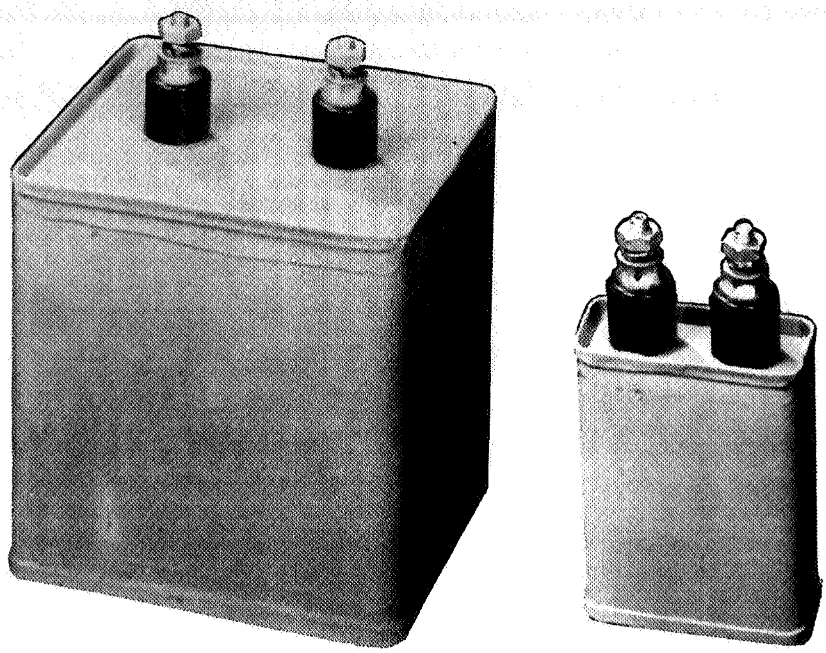

Fig. 11.

LIGHTNING PROTECTION

As an aid in understanding the requirements in lightning protection, that is, the function of an arrester, an explanation of the origin of lightning is in order.

Investigators generally agree that the accumulation of electricity in clouds takes place in the presence of ionized air, moisture in the atmosphere and rising air currents; however, there is considerable uncertainty as to the actual phenomena involved.

Figure 12 illustrates a simple theory for a special case that lends itself to ready explanation. We start with the idea that there is an excess of negative particles of electricity, called electrons, in the air at the surface of the earth. This excess becomes less and less as we move away from the earth. These excess electrons are free to adhere to particles, such as moisture (water molecules), when present in the air.

We next assume that on a warm day when the humidity is relatively high, many molecules of water vapor are present in the atmosphere to which electrons are attached. Now assume that due to some local disturbance at a point on the earth's surface, the warm moisture-laden air at this point starts to rise, with more warm air moving in from considerable distances to take its place, as shown in Fig. 12.

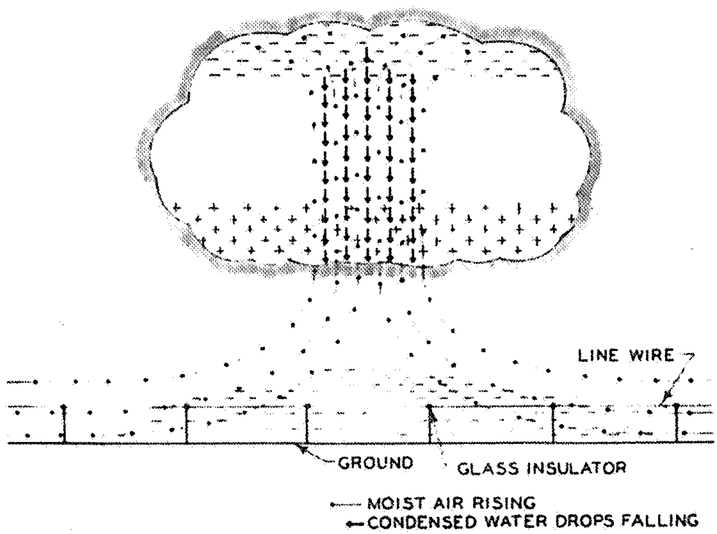

Fig. 12.

When this moisture-laden air reaches a point above the earth where the temperature of the air will no longer keep these water vapor molecules suspended (dew point), some will condense into fairly large drops of water which then fall back toward the earth, down through the column of uprising air. As they reach a point where their downward speed against the force of the rising air is sufficient, these large drops of water break up into a mist, each particle being many times smaller than the original drop.

Some of this mist is suspended by the surrounding air forming a visible cloud while some is carried back up into the colder region, where the particles of mist re-combine and grow into large drops. These large drops fall back into the column of up-rushing air and the cycle is repeated. This process repeats many times. In the meantime, much of the moisture-laden air leaves the column in the form of mist which forms a cloud around this rising column of moisture-laden air.

Excess electrons in the atmosphere, due to their mutual repulsion, tend to distribute themselves uniformly on the surface of water molecules. The large drops of water have much less surface area than the many small drops into which they are divided. Each time the mist droplets form into a large drop of water with its much less surface area, many of the electrons are repelled from the surface of the large drop and distribute themselves to surrounding mist particles, which are lifted to the upper part of the cloud formation.

Conversely, when a large drop of water falling through the cloud breaks up into many smaller drops or particles, with much larger total surface area, they take on electrons from the area at the bottom of the cloud formation. As a result of this process we find the top of the cloud becoming more and more negative because of the electrons accumulated there, and the bottom of the cloud more positive because of the electrons removed from that area and carried to the upper part of the cloud.

This process goes on until the difference in potential between top and bottom of the cloud or between the earth and the bottom of the cloud becomes so great that the accumulation of electrons at the top of the cloud jump to the bottom, or from the earth to the bottom of the cloud, depending on which space has the lower resistance to breakdown. This jumping, or flashover, is, of course, termed a lightning stroke. The flashovers to ground are less frequent than flashovers within or between clouds.

As the electro-positive condition in the bottom of the cloud is building up, it attracts free electrons from the earth up into the line wire where they concentrate under the cloud. In the case of power lines with grounded neutrals, these electrons have a free path, but even with well-insulated ungrounded signal circuits of high insulation resistance, the charge on the line will build up to a high value due to the relatively long time for the cloud charge to build up.

After such a negative charge is built up, there is no potential difference between the line wire and ground because the distribution of electrons is uniform at that location. No current would flow in a conductor connected between ground and the line because the positive charge in the bottom of the cloud would be holding the same excess of electrons at the surface of the ground under the line as upon the line wire.

However, if the positive holding charge at the bottom of the cloud is neutralized by a flashover of electrons from the top to the bottom of the cloud, or from earth at some other point than the line, the excess electrons near the surface of the earth under the line at once return to normal distribution leaving the excess electrons on the line.

With this state we would find a highly uneven concentration of electrons between the line wire and ground. In other words, a high voltage exists between line and ground.

The maximum voltage that a good signal line, with dry, clean glass insulators, can sustain, is about 300,000 volts. If the charge on the line causes a potential that is higher than this it flashes over the insulator down the pole to ground.

If the charge is one that can be sustained by the line, the electrons surge down the line looking for a weak point through which they can get back to earth or to a larger area such as the rails, where they will be less dense, or confined, which in turn means less voltage to ground. An analogy is found where a large dam breaks and the water rushes down the old river bed to a lake where the pressure or head is reduced to a harmless value.

In the case of our signal circuits, this electron flow encounters transformer windings, relay coils, and other apparatus which it tends to destroy, the same as if the aforementioned water encounters a smaller dam in the old river bed which tends to impede this progress. This smaller dam would be destroyed if the water could not flow over the top or by-pass it by flowing over the river bank around it. Likewise, the signal apparatus is destroyed if a by-pass is not provided. From the function it performs, "by-pass" is obviously a more appropriate term than "arrester."

Returning to Fig. 12, if the lightning stroke flashover occurs from line to cloud, the resulting equalization of electron distribution is the same, but in most cases more violent. In the case of Fig. 12, due to the polarity, the current surge would be from ground to the point of flashover.

In the majority of cases, the cloud charges are not as clean and simple as shown in Fig. 12. Due to the turbulence in storm clouds, various sections of the cloud become charged with different polarities, one discharging into the other after the first flashover, with the result that in most cases we find multiple strokes within the clouds of varying degrees and time intervals. The sequence, however, is usually over within a fraction of a second before equalization occurs.

The maximum charge sustained by a signal line (to cause a potential of 300,000 volts) is only approximately 1 ampere-second (6.28×10^{18} electrons). A multiple direct stroke may have 100 ampere-seconds, but 70 per cent have only 10 ampere-seconds.

According to the records, the maximum measured current in any lightning stroke was 500,000 amperes. Likewise, the records show that one of the largest line wires burned off by a lightning stroke was No. 5 copper. Some No. 6 line wires have so suffered but many No. 8 line wires have been burned off. This indicates the sharp division between No. 8 and No. 6 wires in lightning stroke withstandability.

Figure 13 shows a surge moving down a line some distance away from a point where a charge shown in Fig. 12 was released.

In protection against surges, either from released charges or direct strokes, we find that power line protection is a greater problem than signal line protection. This is especially true since, along with the lightning surge current, arrester flashover provides a path to ground and back to the power source for power-follow current.

In the case of ungrounded neutrals where both arresters flash over to carry the lightning surge current to ground, the flashover also provides a path for power-follow current to occur from line to line; or if one arrester flashes over from line to ground at one location and another arrester flashes over at an adjacent location, the power-follow current may flow to and from ground.

The ordinary open wire line has a surge impedance of about 500 ohms, therefore should such a surge arrive at a perfect ground connection, the surge current to ground would not exceed 2 amperes for each 1,000 volts of the charge. The maximum current would therefore be about 600 amperes.

If this ground connection is at the end of a line where a reflection of the surge is experienced, the current to ground can be twice this amount. Surge current to ground would, of course, be much higher if the end of the line were near the point of lightning release or stroke.

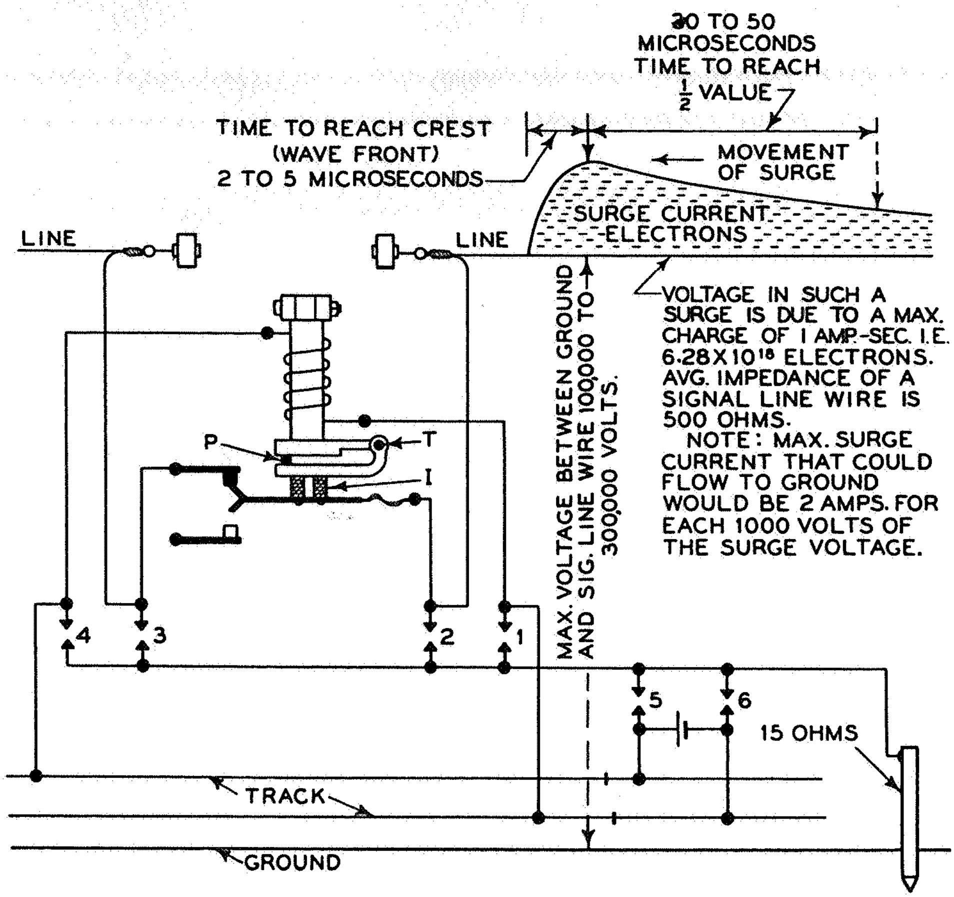

Fig. 13.

The wave front of such a surge is very steep because of the 500-ohm impedance offered by the line wire. A point on the line would experience a voltage rise from zero to crest in 2 to 5 microseconds (2 to 5 millionths of a second) as this surge passed. The tail of such a surge is much longer. It would drop to half the crest value in about 30 to 50 microseconds.

Obviously, in the case of power lines some means must be used to limit the power-follow current following a lightning discharge. This is accomplished by the use of a valve element in series with the gap as a part of the arrester. An ideal current limiting device, which is not presently available, would be one which would not conduct at normal line voltages, but would immediately offer low resistance to the passage of high currents resulting from a lightning surge with a relatively low voltage drop. With such an ideal device, the arrester would not need a spark gap.

Great strides have been made in the development of silicon Zener diodes as voltage regulators. Such diodes are now available that will pass surge currents of several amperes at voltage ratings, from a few volts to a few hundred volts, with a constant IR volt drop at any current.

In this age of development it should not be many years before this perfect flat-top voltage power current limiting material will be available in high voltage ranges and with the capacity to carry the maximum surge current encountered.

Manufacturers' claims now approach this perfection, but even though this perfect arrester is developed, we still will have the problem of dissipating the surge current as it passes out through the arrester.

A ground of 15 ohms is considered a good ground yet a relatively light surge current of 2,000 amperes will result in a voltage drop of 30,000 volts, and the surge current will seek another path to a point of dissipation.

In commercial home service the usual driven ground rod is provided at the distribution transformer but the better path to ground is in the secondary neutral wire which is connected to the driven ground and to the water system in each house serviced.

In signal service the additional path to ground from the power line arresters is provided by the rails. The ground wire and cable messenger wire may be tied together at the line transformer and also the messenger wire may be tied to the ground bus in the relay housing. The other path to the rails is provided by the arresters between the track leads and ground bus. This is illustrated in Fig. 34.

The inherent objectionable feature of a simple spark gap as a power arrester is that the voltage required to produce breakdown of the gap is many times higher than that which will maintain the arc. In an arc a certain voltage is required or spent where the current enters and leaves the metal. For this reason a series of gaps is often used to increase the voltage at which the arc will be extinguished.

Another way of doing this is to provide a suitable metal to metal gap separated by an insulating or semi-conducting member. This arrangement provides for a low voltage sparkover and, when used on low-voltage circuits, will not sustain a power-follow current. The semi-conductor spacer provides an additional path for the surge current, but has too high resistance to maintain power-follow current with low application voltages.

Low-voltage signal and communication circuit arresters do not need current limiting devices in series with the spark gap for there is normally no power-follow current, therefore it is needless to subject the apparatus to the voltage (IR) drop of such a current limiting device.

As originally stated, a lightning arrester is a by-pass unit and should be treated as such. It should be so placed that the surge current will harmlessly by-pass any apparatus in the path it seeks to follow.

When the surge enters the signal housing, Fig. 13, its voltage appears across arresters 2 and 3 to ground, rising in proportion to the wave front. At the same time, this increasing voltage appears between the relay contact and ground.

When this voltage reaches the breakdown of arresters 2 and 3, surge current flows to the ground bus but due to the resistance of the ground, the voltage between the ground bus and ground becomes high, increasing with the surge voltage wave front on the line side of arresters 2 and 3.

With the arrangement of Fig. 13, the surge current on the ground bus will flash over arresters 1, 4, 5 and 6 to the rails.

From the foregoing, we note that an arrester simply discharging to a ground bus does not provide a proper by-pass. It should discharge to the lowest point to which surge current might take a destructive path.

In the case of Fig. 13, this destructive path would be from the relay contact finger across insulators "I" through residual stop pins "P" or trunnions "T" to relay cores, through coil insulation relay leads to rail. In so doing it may weld the residual pins or trunnions, so that the relay will not release when shunted by a train.

It is arresters 1, 4, 5 and 6 that provide the direct path to the rails and by-pass the destructive path. The rails in most cases are the lowest point to which a surge might tend to take a destructive path.

Signal poles and bridges are frequently struck by lightning and, due to the resistance to ground, they may be charged to many thousands of volts higher than ground. This voltage appears between the mechanism attached to the metal pole and the control wires. As the result of the flashover that then occurs, the mechanism and wiring may be damaged.

The mechanism is readily protected because with an arrester connected between the control wires to the mechanism, the voltage across these points cannot rise higher than the arrester breakdown.

Immediately on the flashover of the arresters, the pole, mechanism and terminals of control wires, all become the same potential and it rises with the wave front of the lightning stroke, to many thousands of volts above ground. This high voltage, however, can do no harm as the arresters have by-passed the mechanism and wiring in the destructive paths.

This high voltage quickly recedes as the stroke current leaks to ground down the pole and down the mechanism wires through the arresters to the ground bus in the signal housing and through the track arresters to rails. Some railroads also connect the base of the pole or signal bridge to the ground rod which is also connected to the ground bus.

Considerable knowledge of the characteristics and peculiarities of lightning, and ways and means of affording lightning protection for signal facilities has been gained in the past several decades. The railroads, spurred on by demands for more effective lightning protection, are coordinating their efforts with those of industry in order to evolve the most effective type of lightning protection for a given situation. There are no regions in the United States or Canada where lightning does not constitute a threat to signal apparatus. Modern signal practice requires protection for all apparatus exposed to the effects of lightning.

A lightning arrester is an electrical device used to limit to a safe level the magnitude of voltages impressed across apparatus by lightning and by induced voltage surges. The arrester is designed to operate repeatedly with a minimum of disturbance to the circuit to which it is connected and with a minimum of maintenance. The degree of protection afforded apparatus depends directly on the level or amount of surge voltage the arrester allows to flow in the signal circuit. This level of voltage is determined by the value of voltage required to spark over the gap and start discharge through the arrester and the value of the discharge voltage across the arrester after the sparkover of the gap is established. These considerations are fundamental, regardless of the location or application of the arrester.

Generally, specifications for relays, motors, rectifiers, transformers, etc., used in railway signaling require that coils, transformer and motor windings be insulated and the electrical apparatus assembled to withstand an insulation test of a specified a.c. voltage between all parts of electrical circuits and other metallic parts insulated therefrom. Therefore, lightning protection for railway signal systems requires that the withstand-voltage characteristics of the apparatus to be protected be coordinated with the protective characteristics of the lightning arrester.

Knowledge of the withstand-voltage characteristics of the apparatus and the protective characteristics of various types of lightning arresters can be best obtained by tests. In most instances, manufacturers of such apparatus and arresters can furnish the required information.

Before the advent of laboratory and field research facilities for making exacting studies of lightning surges and their influence on electric systems, there was speculation and conjecture as to the exact nature of the service duty of arresters. Lightning was thought of as direct current, alternating current, high-frequency oscillations, etc.; therefore, the performance of lightning arresters was checked by a variety of direct current and alternating current and sustained high-frequency tests. Instruments such as Klydonographs, surge voltage recorders and principally cathode-ray oscillographs have enabled extensive field studies of the characteristics and behavior of lightning surges, resulting traveling waves and their reflections and short-time impulses in general. The exact shape and duration of lightning impulses on electric circuits have been recorded and artificial lightning generators have been made to reproduce impulses of corresponding characteristics. Thus, much of the mystery has been removed and the art of lightning protection has been distinctly advanced, both as regards the function and specific performance of arresters and the lightning breakdown characteristics of the apparatus insulation. In ordinary power analysis, a cycle, or one-sixtieth of a second, is a common measure. However, the direction of lightning surges into harmless paths requires careful consideration of what can take place in one one-millionth of a second and the microsecond has become the universal time unit in lightning protective engineering. This time unit almost defies conception. A microsecond is to a second what 1 minute is to 23 months or what 1 inch is to 16 miles. The actual service duty of lightning arresters essentially involves their response and behavior under repeated short-time voltage applications.

A cable laid in or on the earth is not immune to lightning disturbances; it needs to be provided with an electrostatic shield. Soil of good conductivity provides a fair shield for cables located in it, but where the soil conductivity is poor, that is not the case. Cable systems are more liable to be troubled by lightning at the point where they connect to open-line wires. Protection is mandatory at these points.

A lead-covered cable with sheath grounded provides a perfectly shielded circuit because the sheath completely surrounds the conductors. In open-line construction this high degree of shielding may be approached by means of a grounded continuous shield wire installation by the use of which overhead open-line wires may be made more secure against lightning disturbances. Any grounded conductor near any circuit will so divert the electrostatic field from a cloud that the voltage induced in the circuit will be less than if the grounded conductors were not there.

The degree of shielding afforded by overhead ground wires is not a fixed quantity. Their value in reducing lightning voltages on a line depends on several things—the number of ground wires used, their position relative to the protected circuits and to each other, the height of the lines and the ground wires above the earth, the conductivity of the soil under the lines and the number and resistance of the earth connections to the ground wires. One ground wire directly over the circuit will afford a certain amount of protection. Under most favorable circumstances it may reduce the induced voltage to 60 per cent of that which would occur under the same conditions without the ground wire. Two ground wires are better than one and additional wires at the sides of the circuit will still further improve conditions. Such an installation is, in effect, an approach to a shielded cable.

The modern lightning arrester is a highly protective device. High-voltage arresters consist essentially of a spark gap set to flash over at some predetermined voltage, and in series with the gap is what is known as a valve element. Low-voltage arresters may or may not use a valve element, depending on the application.

Considering their protective characteristics only, lightning arresters have one function to perform; that is, to hold the impulse voltage across the equipment to a safe value. However, arresters when connected to circuits carrying comparatively high line voltage and current, must possess valve characteristics that will positively cut off power current flow to ground following a lightning discharge through them. If these lightning arresters do not have positive valve characteristics they represent a hazard to the circuit on which they are installed, causing unnecessary grounds and short circuits because of their failure to properly interrupt the flow of system current following the lightning discharge to ground. This results in fuse blowing and unnecessary outages.

The best approach to the solution of the many problems attending lightning arrester design or application has been found to be through laboratory studies of arresters, using modern testing and evaluating equipment, and through actual field performance studies of the arrester over a long period of time under widely diversified conditions. As a result of these studies, the characteristics of the arresters, such as impulse sparkover, IR discharge voltage and discharge capacity are published in manufacturers' bulletins. These values can then be compared to the withstand characteristics of the apparatus to be protected.

Lightning arresters are given a maximum voltage rating by the manufacturer. This rating is found on the name plate, carton, label, etc. Oftentimes, both a.c. and d.c. voltage ratings are given. These ratings are the highest circuit voltages to which the arrester may be safely connected.

TYPES OF ARRESTERS

Signal transmission lines—outdoor type.

Lightning arresters for the protection of signal transmission lines of the higher voltages are subjected to heavier discharge currents due to greater exposure to lightning and therefore they are designed for higher discharge capacity as well as for the higher line voltage. The arrester used for this service is the valve type. It is essentially a non-linear resistance valve element in series with closely spaced gaps. Under normal conditions, the gap structure insulates the line from ground, but when a lightning surge occurs, it sparks over to conduct the surge to ground through the non-linear element. The valve element provides lower impedance to surge current, but higher impedance to power-follow current due to the difference of applied voltages. In other words, the valve element is a resistance which has the characteristic of having a low resistance with a high applied voltage and a high resistance at relatively lower voltages. The high value of surge current from lightning (high voltage) passes readily because the valve offers a low resistance path. The power voltage cannot maintain the low value of resistance and the resistance of the valve therefore keeps increasing so as to quickly reduce the power-follow current to a value which can be interrupted by the series gap. Some distribution valve type arresters have an additional component called an isolator or ground lead disconnector which isolates the arrester from ground in the event that the valve element is damaged by lightning to the extent that it allows transmission current to flow to ground. Some valve type arresters are equipped with an external gap which provides the same isolation, although with its use the sparkover value is increased. Distribution valve type arresters are available in voltage ratings of 1 through 18 kilovolts.

Figure 14 shows a distribution valve arrester designated as the Type E3. The gap structure consists of a number of parallel electrodes which are accurately positioned and retained by the two insulating plates. The number of electrodes in a unit is dependent upon the arrester voltage rating and is chosen to give a performance which balances 60-cycle sparkover, impulse sparkover, and power-follow current interrupting ability.

The valve element is a stable refractory crystalline material, which combines the desired valve action with high discharge capacity. The gap structure and valve element are sealed in a Pyrex glass housing. All parts of the gap construction are visible, thus allowing a determination of previous arrester operating duty and revealing any arrester damage.

A fiber glass cap serves to insulate the top copper cap and is attached to the housing.

The isolator serves to automatically disconnect the ground lead from the arrester in the event that the unit is electrically damaged. When the isolator operates, the detached ground lead is visible from the ground, giving positive indication that the arrester should be replaced.

The isolator consists of two electrodes sealed in a phenolic resin housing. The upper electrode connects electrically to the valve element. The lower electrode contains a combustible powder, connects to the ground lead.

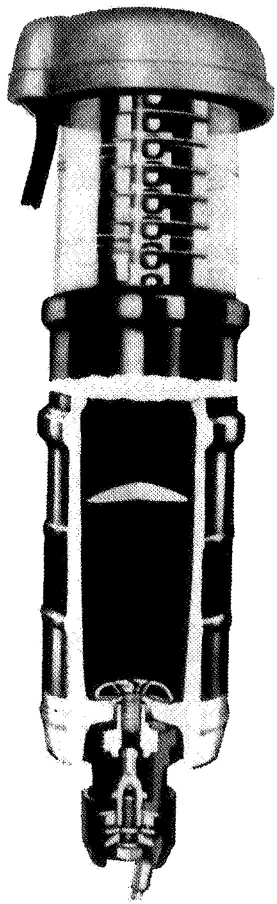

Fig. 14.
Distribution Valve Type Arrester
(Cut-Away View).

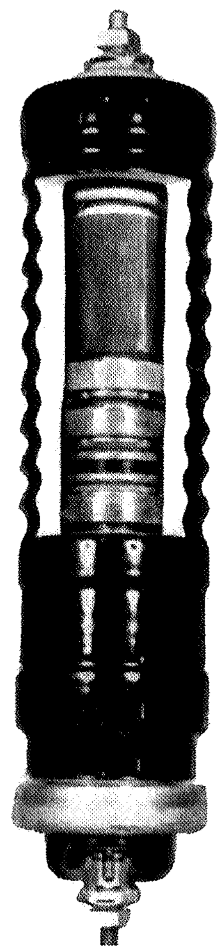

Fig. 15.
Magne-Valve Distribution Lightning Arrester
(Cut-Away View).

If the valve element is damaged by extreme operating circumstances, power-follow current continues to flow to ground, thereby heating the isolator electrodes. The heat ignites the combustible powder and the expanding gases of combustion cause rupture of the isolator housing. As a result, the ground lead is disconnected from the arrester.

To insure proper distribution of surge current over the entire cross-section of the valve material, a lens-shaped electrode is used in the lower end of the valve element. In the 12 and 15-kilovolt arresters, an additional lens-shaped electrode is placed midway in the length of the column. These electrodes are proportioned to compensate for "skin effect," consequently all parts of the valve element are used with a maximum of efficiency.

Figure 15 illustrates another type of valve arrester called the Magne-valve Distribution arrester. The Magne-valve action consists of the magnetic action of a series-gap operating in conjunction with the valve action of Thyrite discs. This arrester discharges lightning surges to ground in the same manner as other valve-type arresters. However, when the power-follow current begins to flow, a magnetic field is created across the arc gap. The force created by this field causes the arc to rotate rapidly around concentric electrodes. This action helps to cool the arc and causes its extinction at the end of the half-cycle in which the surge occurs. This arrester is provided with a disconnector which will disconnect the ground lead from the arrester in the event the arrester has failed to the extent that allows power-follow current to flow to ground for a

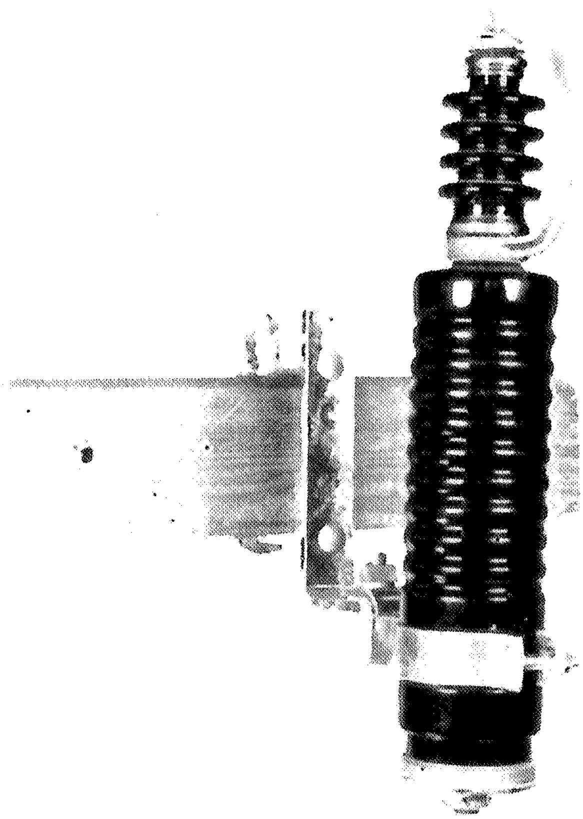

Fig. 16.
External Gap Magne-Valve Distribution Lightning Arrester.

given time after surge current. This is accomplished by the inclusion of a cartridge of combustible powder near the ground lead terminal. The cartridge is not affected by surge current, but in the event of arrester failure power-follow current will flow in a path which has a fusible element directly over the detonator of the cartridge. When the arrester fails, the element melts from power-follow current flow, which in turn creates an arc close to the cartridge. When the cartridge detonates, the weakest section by design is ruptured and the ground lead is separated from the arrester by several inches.

This arrester is also available with an external gap instead of the ground lead disconnector to prevent line lock-out. The use of the external gap will, of course, raise the sparkover value to some extent. However, it provides a reliable means to prevent line lock-out, and its life is not limited by erosion of internal parts. Figure 16 shows this external gap feature of the arrester.

Figure 17 illustrates a Crystal Valve lightning arrester which essentially consists of an arcing unit assembly of accurately spaced brass discharge plates capable of handling many lightning discharges with little deterioration; the spacers for the discharge plates are accurately ground ceramic insulators. The top of the arcing unit is terminaled outside the porcelain body for connection to the transmission line. The bottom of the arcing unit rests on a column of crystals that are packed into the glazed porcelain body. These crystals form the valve or characteristic element of the arrester. The ground terminal is sealed into the base of the column of crystals.

The length of the spark gap element and the column of crystals is dependent on the voltage for which the arrester is designed. The higher the voltage the

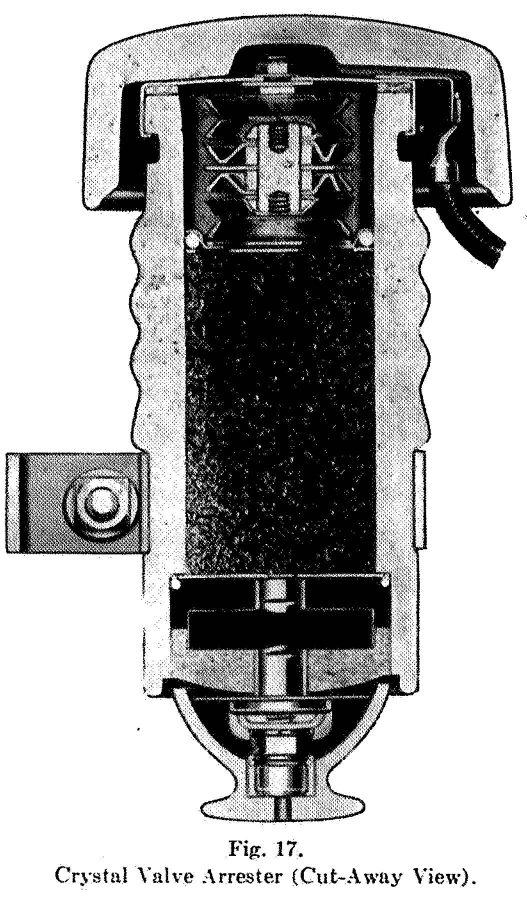

Fig. 17.
Crystal Valve Arrester (Cut-Away View).

longer the spark gap assembly and the column of crystals. This arrester is also available with a ground wire disconnector.

Another type of valve arrester, called the Autovalve, is shown in Fig. 18. It consists of a series of cylindrical blocks of porous material with comparatively high resistivity, connected through a series gap between line and ground. Even though the resistivity is comparatively high, the resistance through which the discharge flows is low since the cylindrical block has a large area. The top of the spark gap is terminaled for connection to line while the base of the cylindrical porous block rests on the terminaled connection for ground. The arrester is enclosed in porcelain.

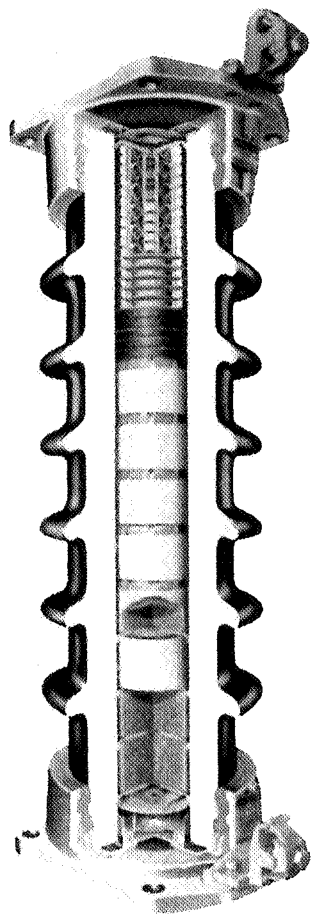

Fig. 18.
Autovalve Arrester (Cut-Away View).

Under normal conditions no current flows through the arrester. When lightning strikes the line, the voltage begins to rise across the arrester and across the other insulation to be protected by the arrester. The increased voltage appears across the series gaps. The isolating gap is ionized by the pre-ionizing tips conditioning the gap for consistent sparkover. When the voltage reaches sparkover value of the gap, there is a discharge in the series of spark gaps between the metal electrodes. The arrester is then conducting and the lightning current flows through the autovalve block elements to ground. These blocks have low resistance to lightning currents and during the flow of these currents the voltage drop across the arrester is limited to a low value. Power current is interrupted at the first zero current value, thereby restoring arrester to its initial position as an insulator. This arrester is equipped with a drop-out feature which disconnects the ground connection if arrester is damaged.

Figure 19 shows another valve arrester, designated Type S-3, for protection of secondary circuits in the range from 0-650 volts. While the secondary lines are not usually as long as the primaries, they are nevertheless subject to lightning surges. This arrester design consists of a spark gap with low impulse sparkover and a valve element of low IR drop connected in series between line and ground. The gap isolates the line from ground under normal conditions, but when a surge occurs it sparks over the gap and flows to ground through the valve element. The resistance of the element is such that power-follow current is interrupted at the first current zero by the gap. The spark gap consists of two flat plates of a special alloy separated by a spacer ring of heat-resisting glass which is ground to close tolerances. Between the plates is a ball electrode which is exactly dimensioned to allow it to roll in the space between the plates. This design provides a quick-acting gap and low sparkover. The Pyrex glass body of the arrester permits visual inspection of the gap or the valve element.

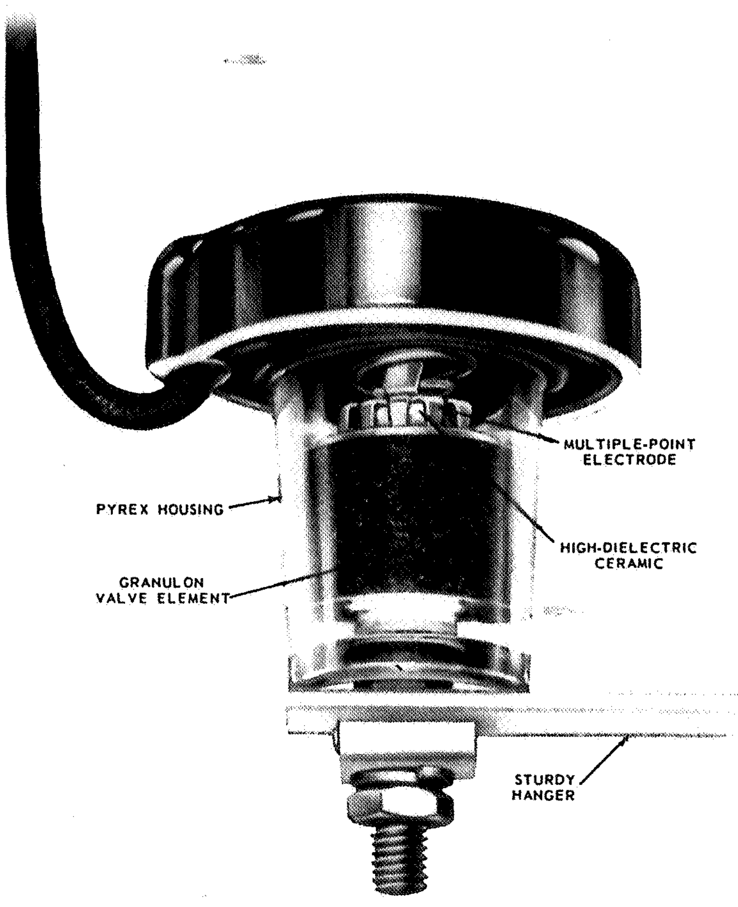

Fig. 19.
Secondary Arrester—Single Pole.

Figure 20 shows a cut-away view of a Pellet type arrester designed for ratings of 1 through 15 kilovolts. It consists of one or more series gaps connected to the line lead at the top of the porcelain tube in a gasket sealed chamber. The valve column consists of coated lead dioxide pellets that fill the lower part of the porcelain tube and are in electrical contact with the ground lead. The

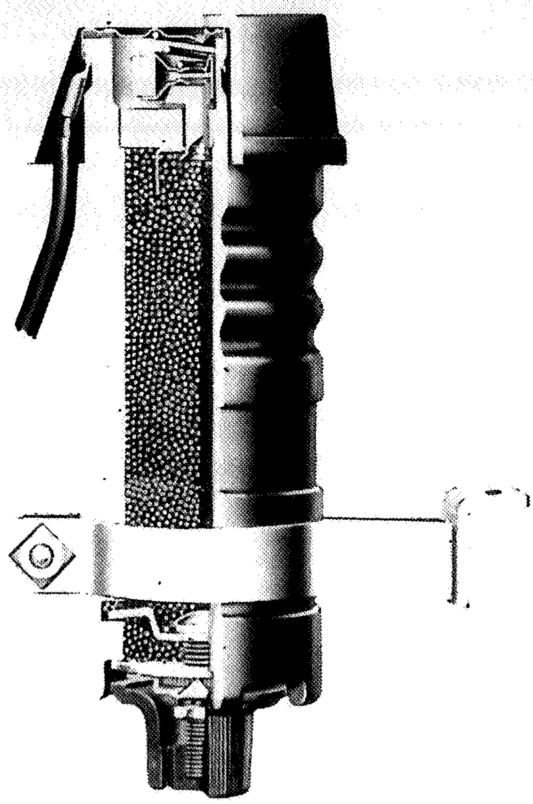

Fig. 20.
Pellet Distribution Lightning Arrester (Cut-Away View).

number of arc gaps and the length of column of pellets is dependent on the line voltage for which the arrester is designed.

A Pellet type arrester, designed for 0-650 volts, is shown in Fig. 21.

Figure 22 is a Valve type secondary arrester designed for cross-arm mounting comprised of a series of air gaps between homogeneous carbon discs and silicate of carbide discs enclosed in a porcelain housing. The discs provide large surfaces between which repeated discharges may pass without affecting the operating characteristics of the arrester.

The number of series gaps used is dependent on the line voltages for which the arrester is designed. Two ratings are available: one for 110 to 250-volt lines and one for 440 to 750-volt lines. The arrester is designed for protection of both sides of supply line to ground.

Signal control circuits—indoor type.

Signal control circuits are subjected to discharge currents of less magnitude because of less line exposure, more shielding and more frequent use of arresters on the line for a given distance. Arresters for this service have a lower discharge capacity than is required for high voltage service. All the many types available are designed for mounting on AAR terminal blocks and for use indoors or in weatherproof boxes.

These arresters are either of the valve type, i.e., a valve element in series with the gap electrode, or a gap or gaps without the valve element.

The low breakdown gap type of arrester without the valve element is the most effective in protecting low power signal circuits. Valve material in series with the gap, however good it may be, does not reduce to zero impedance on a

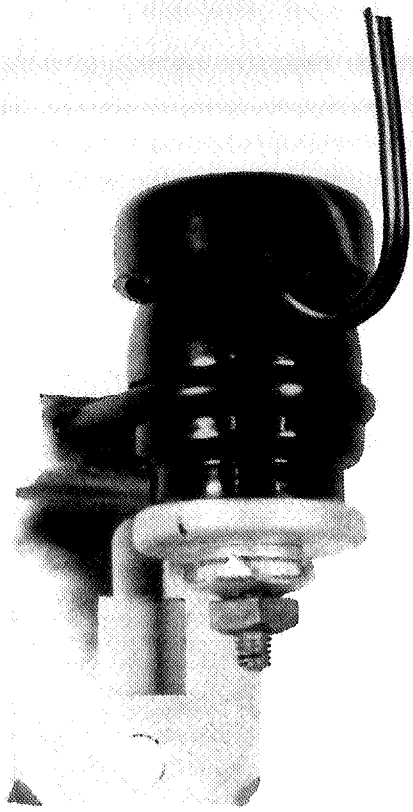

Fig. 21.
Pellet Type Lightning Arrester.

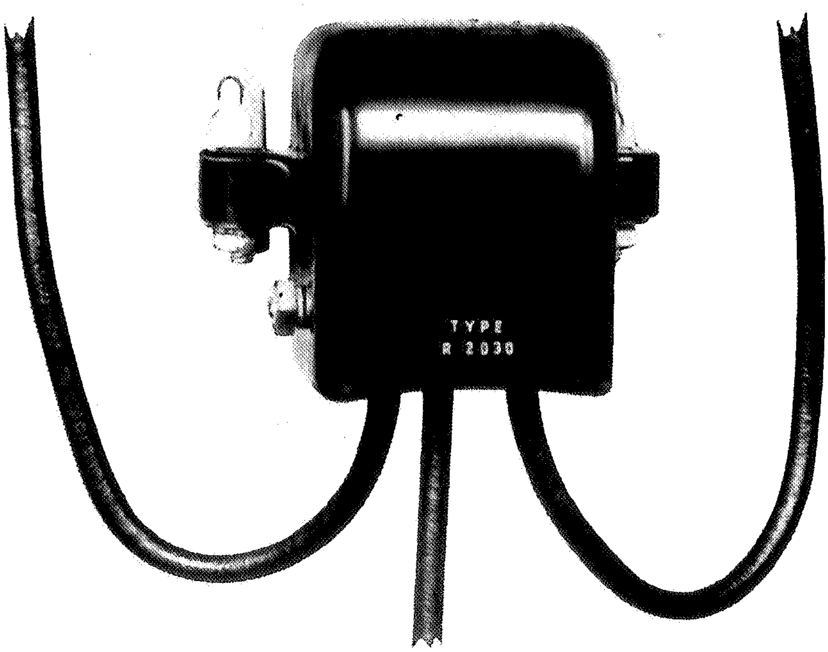

Fig. 22.
Valve Type Secondary Lightning Arrester.

lightning discharge and on high current impulse test the IR drop across the valve element exceeds the breakdown voltage of the gap. The non-valve type gap arrester is therefore very effective on signal circuits where power-follow current is insignificant due to the low voltage and inherent series impedance of the circuits which allow the arc to be extinguished by the gap alone.

Low-voltage signal arresters may be connected between line and ground, line to line in shunt with apparatus terminals, or ground to track, as indicated in Fig. 34, within their rating as established by the manufacturer. Some of the arresters of this type are herein described.

The Thyrite valve type signal lightning arrester shown in Fig. 23 consists of a molded insulation base equipped with clips for mounting. Into this base the Thyrite signal arrester assembly is inserted. The removable arrester unit consists of a transparent housing which encloses the serrated gap electrode in series with the Thyrite valve element. The rating is 0-175 volts a.c., 0-50 volts d.c. on unlimited capacity circuits and 0-300 volts d.c. on centralized traffic control circuits having direct current of 0.5 ampere or less. These arresters may be connected between line and ground or line to line in shunt with apparatus terminals.

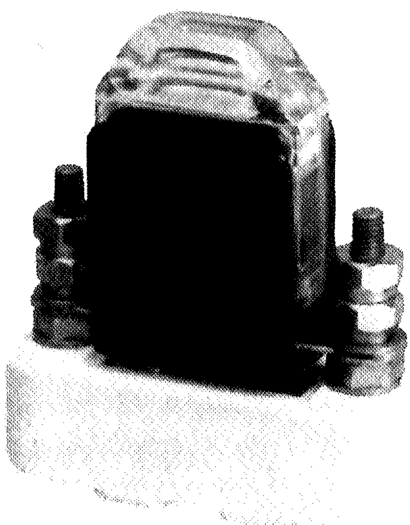

Fig. 23.
Thyrite Signal Lightning Arrester.

Another valve type signal arrester, known as the Type L, is designed to protect low-voltage circuits of 0-175 volts a.c. or 0-125 volts d.c. This arrester is a sealed unit consisting of a precision spark gap, a high discharge capacity valve block, a clear plastic housing, a bakelite base, and non-corrosive terminal straps. Phosphor-bronze spring clips hold the gap and valve block rigidly in place and the assembly is gasket-sealed to make it moisture-proof. Five blunt fingers and a heavy brass disc form the spark gap. A ceramic insulator separates the fingers from the disc. A similar brass disc on the ground side of the valve element dissipates the heat generated by the arc across the gap, and distributes the surge throughout the cross-section of the block. In the event of a high surge current which might damage the arrester, the fingers will burn back and clear the power-follow current. The valve element is designed to pass heavy discharge currents without damage and a silver coating on the flat surface maintains proper conducting qualities.

The stainless steel terminal straps extending from the underside of the base are slotted for easy mounting. Figure 24 shows the Type L arrester with housing removed.

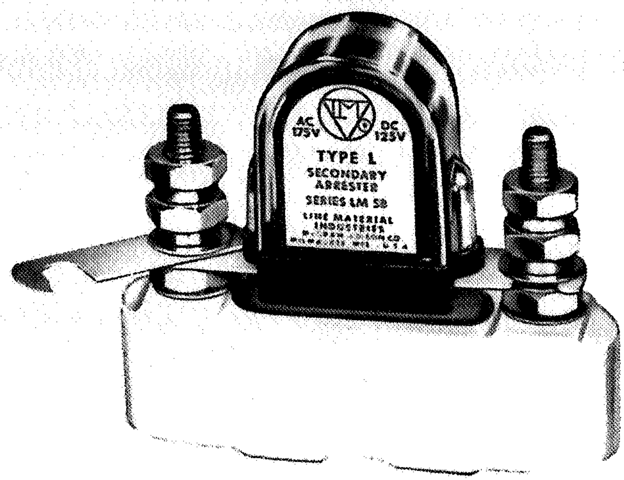

Fig. 24.
Type L Signal Lightning Arrester.

Figure 25 shows another low-voltage Crystal Valve arrester, known as the Type LAV. This arrester is designed for a voltage rating of 0-50 volts d.c. and 0-175 volts a.c. The spark gap is of the duplex type, with operating electrode surface having three "V" edges which are formed from non-corrosive electrode material. The duplex electrode is pressed on an accurately ground ceramic block and these two are permanently held by pressure against the metallic sealing of the cover of the body. The arrester cartridge has a spring clip on each of its vertical sides. The horizontal ends of the clips are provided with holes properly spaced so that the arrester with the clips can be slipped over the studs on the terminal. The valve element of the Type LAV arrester consists of a special form of silicon carbide, known as Crystallite.

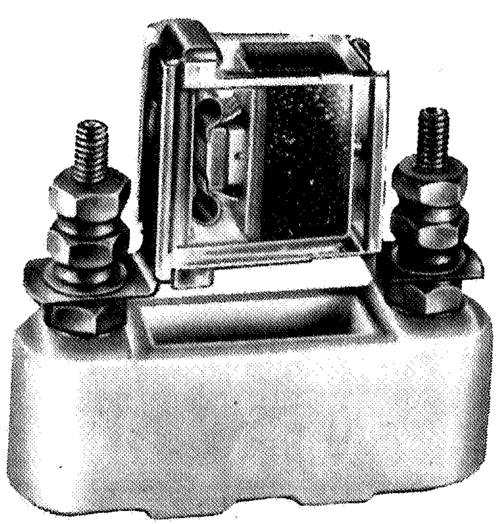

Fig. 25.
Type LAV Lightning Arrester.

The Rare Gas type of lightning arrester illustrated in Fig. 26 consists of a glass tube enclosed by an insulated jacket and has plug-in contacts. The glass tube contains a rare gas, in which are sealed two electrodes accurately spaced, between which the electrical discharge passes when the electrical circuit is dissipating an over-voltage surge. Lightning arresters of this type can be connected between line and ground and across the terminals of any instrument that is to be protected.

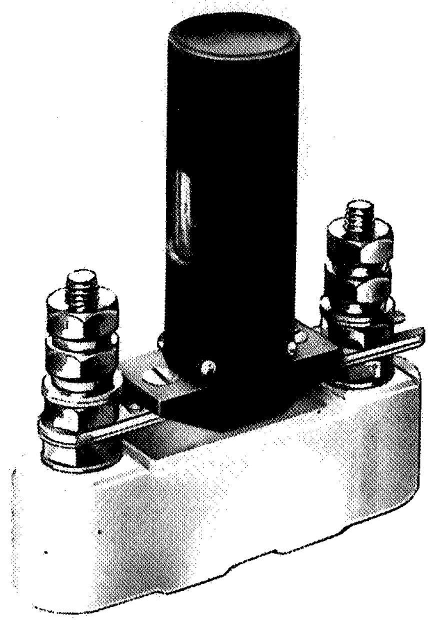

Fig. 26.
Rare Gas Signal Lightning Arrester.

There is an Autovalve type of low-voltage arrester, illustrated in Fig. 27, suitable for use on circuits 0-75 volts d.c. and 0-175 volts a.c. Its operating elements consist of a current-limiting autovalve block and a spark gap in series. The dielectric characteristics of the block permit high surge current to pass through it to ground. With low voltage, however, it has the properties of an insulator and this, together with the air gap, prevents the flow of power-follow current to ground. The multiple spear-pointed form of the gap electrode opposite the block provides two advantages: (1) When an excessive discharge from any cause injures the block so that it cannot interrupt the power-follow current, the current flowing through the point will melt it back until the circuit opens; (2) The remaining points enable the arrester to still perform its essential low sparkover protective function. The housing blackens when damage occurs, which may indicate need of replacement.

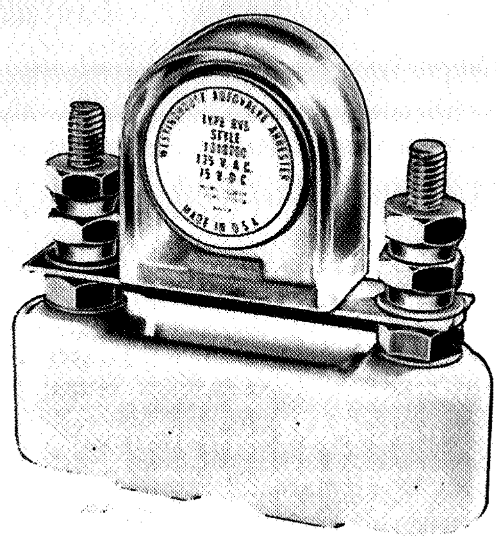

Fig. 27.
Autovalve Signal Lightning Arrester.

The Clearview two-gap resistance block type of arrester, illustrated in Fig. 28, has two air gaps, (1) metal to resistance block and (2) metal to metal. The smaller gap, metal to resistance block, provides a low impulse breakover and ionizes the larger gap. The high internal resistance of the resistance block readily passes the small current necessary for ionization of the air between the metal gaps, but its high resistance prevents it from carrying enough current to maintain a power-follow arc after the single discharge. The arc, if any, must be between the metal plates, which on account of their design and spacing quickly extinguish the arc or burn back to a point where the arc is extinguished due to the gap being widened.

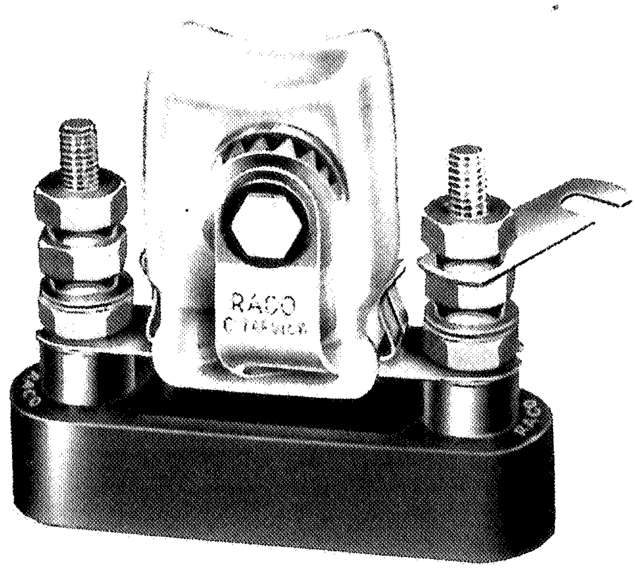

Fig. 28.
Clearview Signal Lightning Arrester.

Figure 29 shows another type of arrester, called the USG lightning arrester. This arrester has two alloy electrodes which are separated by an insulating member and which are held together rigidly with tension maintained by a substantial rivet and spring member which do not carry the surge current. Due to this feature and to the shape of the electrodes which make them self-clearing, this arrester maintains uniform characteristics for hundreds of high current discharges. The arresters are treated to obtain and maintain breakdown voltages considerably lower than are usually obtained with gap type arresters. The cover permits venting of the arc and gases at sparkover. One type of USG arrester, distinguished by red marking, maintains an impulse breakdown between 500 and 1,200 peak volts and is especially useful for series protection and for shunt protection of higher voltage circuits. These arresters, being conditioned for proper operation should not be subjected to megger testing voltage which is greater than the breakdown voltage of the arrester.

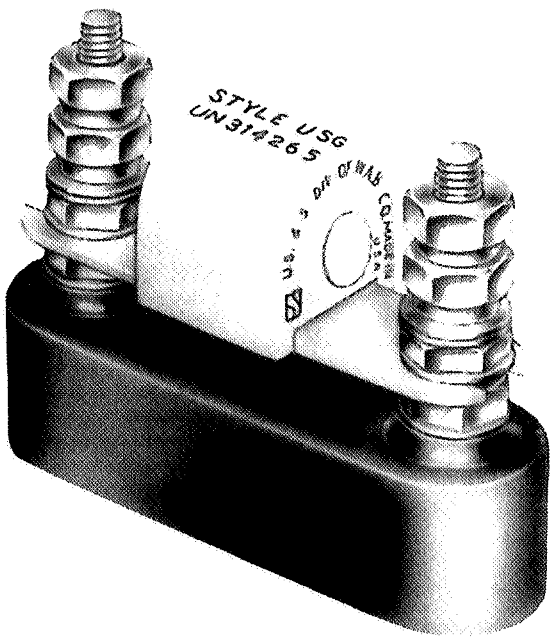

Fig. 29.
USG Lightning Arrester.

Arresters, Equalizers and Discharge Resistors for Shunt Protection of Track Circuit Equipment, Lamp Filaments and Other Applications Where Voltage Does Not Exceed 30 Volts

Experience has proven that the track rails provide a very reliable ground connection for lightning arresters inasmuch as they have not only relatively low ballast resistance to earth, but also represent an enormous counterpoise of distributed capacitance and close coupling to earth. However, due to the close association between the track rails and the signal apparatus, it is not desirable to use the rails for grounding purposes unless proper protective devices, such as track arresters, equalizers or discharge resistors, are used. These non-valve type gap arresters, equalizers or discharge resistors have the property of presenting a high resistance to normal track circuit voltages, but readily permit passage of current resulting from high impulse voltages. The lower the impedance drop during sparkover, the better the protection afforded equipment.

Several types of these units are described in the following:

An Equalizer, illustrated in Fig. 30, similar in design to the Clearview arrester, except that the air gaps have been eliminated, lowers the impulse breakdown to 300 volts or less, but at the same time makes a closed circuit of such high resistance that track circuit voltages cannot pass through. The unit is colored black to readily identify it as an equalizer and in addition the discharge unit is of a design that cannot be placed in Clearview arrester clips. The equalizer may be also used for lamp filament protection.

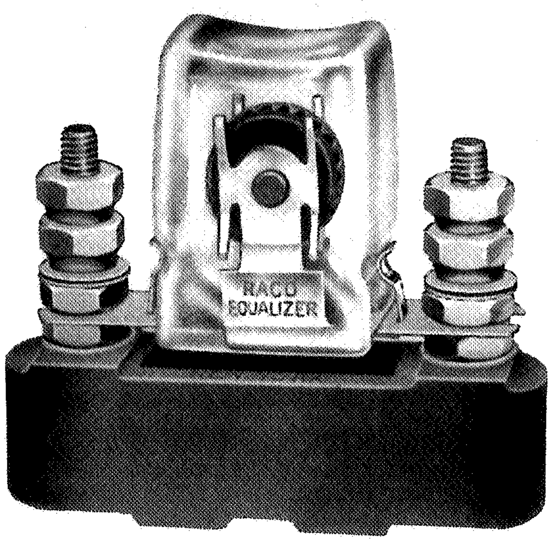

Fig. 30.
Equalizer.

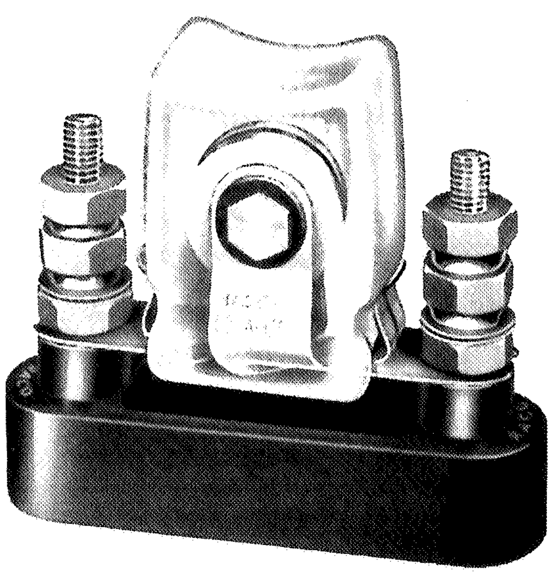

Fig. 31.
Heavy Duty Equalizer.

A Heavy Duty Equalizer, illustrated in Fig. 31, is designed for use in extremely heavy lightning territory, maintaining the same protective ability of equalizer, Fig. 30, but of heavier construction and additional venting to better withstand extreme lightning and surge voltages.

The low-voltage USG arrester for this service is the same as the arrester shown in Fig. 29, but is distinguished by black markings. The gap is somewhat smaller so that the arrester maintains an impulse breakdown of under 300 peak volts. This arrester may also be used for lamp filament protection. These low-voltage arresters must not be subjected to megger or other test voltage as it will disturb the preconditioned breakdown voltage of the arrester. Arrester resistance may be measured with the usual ohmmeter.

A Thyrite Discharge resistor rated at 130 volts a.c. or d.c. for interconnection of high-voltage and low-voltage signal arrester ground to track rails is illustrated in Fig. 32. It consists of two valve material discs, one on either side of a central terminal plate, and with terminal connections to each of the other outside surfaces. These valve material discs have an inverse resistance-current characteristic so that they will not pass an appreciable amount of current at signal voltages but will pass large amounts of lightning discharge currents with relatively low IR drop.

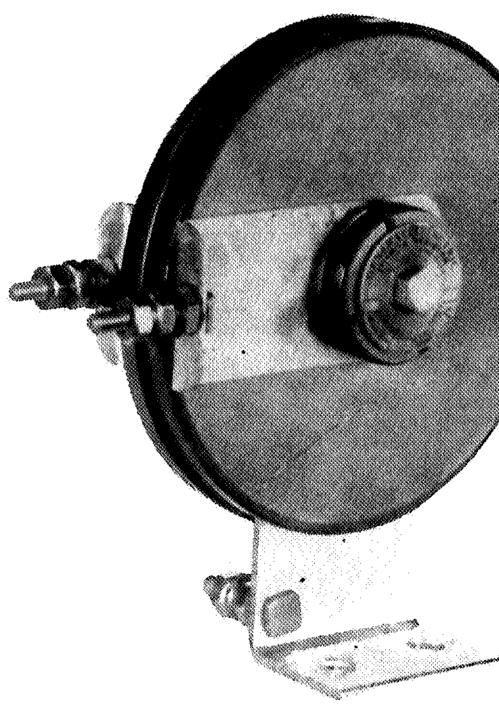

Fig. 32.
Thyrite Discharge Resistor.

Arrester Grounds and Applications

The effectiveness of the lightning protection afforded by lightning arresters is dependent on the arrester ground having a low resistance. An acceptable ground resistance should be less than 15 ohms—the lower the better. A recommended type of ground rod is shown in Fig. 33, which also shows ground rod clamps and method of wire connections. The rod is located as close as

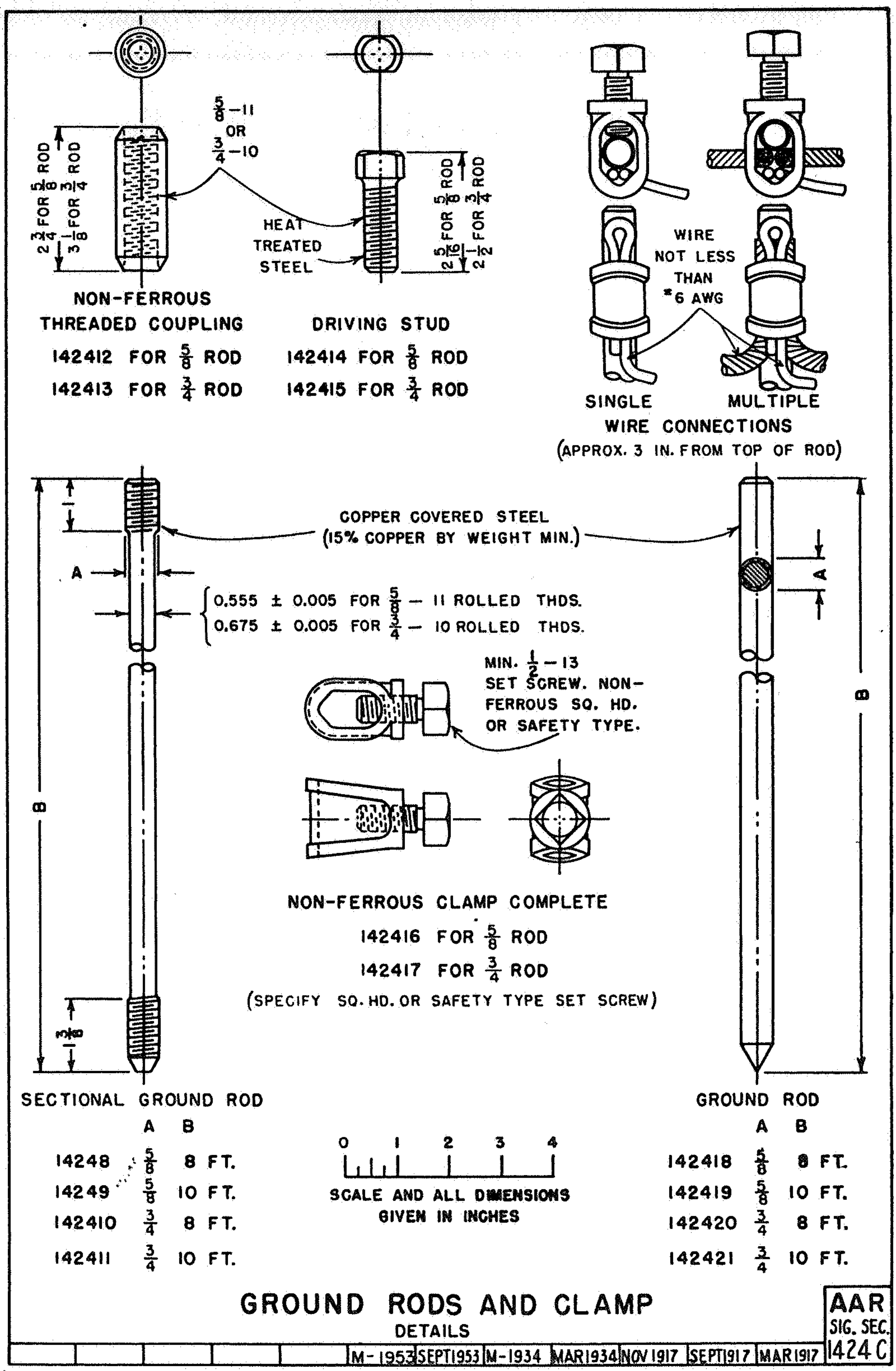
5/8-11 OR 3/4-10
2 3/4 FOR 5/8 ROD
3 1/8 FOR 3/4 ROD
HEAT TREATED STEEL
2 5/16 FOR 5/8 ROD
2 1/2 FOR 3/4 ROD
NON-FERROUS THREADED COUPLING
142412 FOR 5/8 ROD
142413 FOR 3/4 ROD
DRIVING STUD
142414 FOR 5/8 ROD
142415 FOR 3/4 ROD
WIRE NOT LESS THAN #6 AWG
SINGLE
MULTIPLE
WIRE CONNECTIONS
(APPROX. 3 IN. FROM TOP OF ROD)
COPPER COVERED STEEL
(15% COPPER BY WEIGHT MIN.)
A
0.555 ± 0.005 FOR 5/8 — 11 ROLLED THDS.
0.675 ± 0.005 FOR 3/4 — 10 ROLLED THDS.
MIN. 1/2 — 13 SET SCREW. NON-FERROUS SQ. HD. OR SAFETY TYPE.
B
NON-FERROUS CLAMP COMPLETE
142416 FOR 5/8 ROD
142417 FOR 3/4 ROD
(SPECIFY SQ. HD. OR SAFETY TYPE SET SCREW)
SECTIONAL GROUND ROD
A B
14248 5/8 8 FT.
14249 5/8 10 FT.
142410 3/4 8 FT.
142411 3/4 10 FT.
0 1 2 3 4
SCALE AND ALL DIMENSIONS GIVEN IN INCHES
GROUND ROD
A B
142418 5/8 8 FT.
142419 5/8 10 FT.
142420 3/4 8 FT.
142421 3/4 10 FT.
GROUND RODS AND CLAMP
DETAILS
AAR SIG. SEC. 1424 C
M-1953 SEPT1953 M-1934 MAR1934 NOV1917 SEPT1917 MAR1917

Fig. 33.

practicable to the lightning arresters, but preferably not less than 3 feet from any post, pole or foundation. Where space is not available to drive the rod vertically, it is driven at an angle so that the lower end is more than 3 feet from the post, pole or foundation. The rod is driven into the ground at least 8 feet wherever practicable. In instances where more than one rod is required to obtain a satisfactory ground, they are spaced at least 6 feet apart.

The wire connections to the rod or rods are copper, not less than No. 6 A.W.G. in diameter. They are run as directly as practicable, avoiding sharp bends, and have sufficient slack to avoid breakage from the effects of frost. An air space of not less than 3/8 inch, or equivalent insulation, should be provided between ground wire connections and operating circuits.

The resistance between the ground rod and the surrounding earth should preferably not exceed 15 ohms. Resistance is measured using an approved instrument, and the manufacturer's instructions should be followed.

Where the desired resistance cannot be obtained by a single, multiple, or sectional ground rod further reduction in resistance may be obtained by treating the soil. This is accomplished by digging a circular trench approximately 15 inches wide, 18 inches deep, and 48 inches in outside diameter around each rod, distributing 50 to 75 pounds of rock salt, depending upon soil resistivity, in the trench, flooding the trench with water two or three times and then replacing the soil in the trench.

Where the arrester location is on top of a fill and the desired resistance of ground is not obtained at the arrester location, a supplementary rod or rods may be driven at the foot of the slope where soil conditions provide a good ground, or ground rods may be driven under the track at an angle of about 45 degrees, observing maintenance-of-way requirements. In such cases the ground rod at the arrester location is retained.

With conventional separate ground connections for primary arresters, when there is a heavy discharge through the primary line arresters, the current is of such a high value that, even with a low ground resistance, the IR drop from the ground rod to earth is of large value. For example, a discharge of 5,000 amperes through a 10-ohm ground resistance would result in a momentary voltage of 50,000 volts. This voltage to earth plus the voltage across the primary arrester is impressed between the transformer primary terminals and earth. It would probably result in a bushing flashover from primary to transformer tank and thence to the secondary circuit, permitting a portion of the energy to reach signal apparatus on the low-voltage side.

An arrangement to reduce the possibility of damage from these circumstances is shown in Fig. 34. This arrangement of lightning arresters has been proved to afford the best protection against lightning damage to signaling circuits. The use of discharge resistors, equalizers, or low-voltage non-valve type gap arresters for rail connection of ground bus to the rails will provide maximum protection.

One of the important features of this arrangement, which cannot be overemphasized, is the interconnection of all grounds, signal masts and cases housing signal apparatus for the purpose of limiting any voltage differential to the withstand voltage of the apparatus.

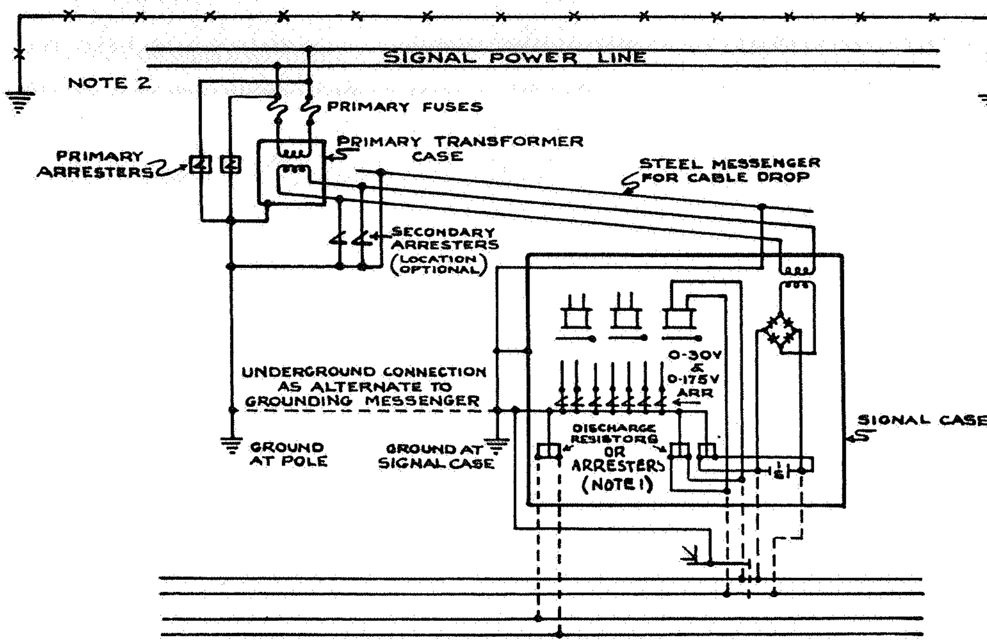

Fig. 34.
Overhead Ground Wire Extending Several Poles Either Side of Transformer Location.

Notes for Fig. 34.—

1. (a) For maximum protection, discharge resistors, equalizers or non-valve type gap arresters should be used.

(b) Where a maximum degree of protection is not required, standard low-voltage signal lightning arresters may be used. They must be installed between each rail lead and the common ground bus.

2. Overhead ground wire extending several poles either side of transformer location. Overhead ground wire or shield should have 8 feet or more vertical clearance from all power and signal wires. Down leads from shield wire should have 4 feet 3 inches or more clearance from all other wires and the grounds should not be closer than 10 feet to any other ground or buried conductor. Total resistance of the shield wire grounds in multiple should not exceed 4 ohms.

3. ~~These~~ Arresters are mounted as close as practicable to the apparatus to be protected.

American Railway Signaling Principles and Practices

QUESTIONS ON

CHAPTER XXIV

SIGNAL POWER TRANSMISSION
AND
LIGHTNING PROTECTION

QUESTIONS ON CHAPTER XXIV

SIGNAL POWER TRANSMISSION

1. What frequency is generally used for alternating current in railway signaling?

2. What kind of wire is ordinarily used in constructing signal power transmission lines?

3. What kind of transformer is used where the primary voltage is under 600 volts?

4. By what means can the power factor be increased when the inductive load is high?

LIGHTNING PROTECTION

5. What maximum voltage can a good signal line with clean dry insulators sustain without flashover?

6. Are there any regions in the United States or Canada where lightning protection for signal apparatus is not required?

7. What is the purpose of a lightning arrester?

8. What time unit is used in the study of lightning and its effects?

9. What is the purpose of the valve characteristic in high-voltage arresters?

10. Where may the rating of an arrester be found?

11. What means are sometimes used to disconnect the ground lead when the arrester has been damaged?

12. What is the maximum resistance of what is termed an acceptable ground?

13. What is the preferred location of ground rods in its relation to the lightning arresters?

14. What kind of wire is used to ground rod and what is its minimum size?

15. For what kind of mounting are low-voltage arresters usually designed?

16. How much air space should be provided between ground wire connections and operating circuits?

17. Why is it necessary for the arrester ground to be of low resistance?

18. What means are sometimes used to reduce ground resistance when desired resistance cannot be obtained by a single ground rod?

19. What is the purpose of the discharge resistors as applied in Fig. 34?

20. Why are the ground connections of case, signal mast, messenger cable, etc., interconnected as shown in Fig. 34?

AMERICAN RAILWAY SIGNALING PRINCIPLES AND PRACTICES

Following are the titles comprising this series of educational chapters:

* Under preparation.