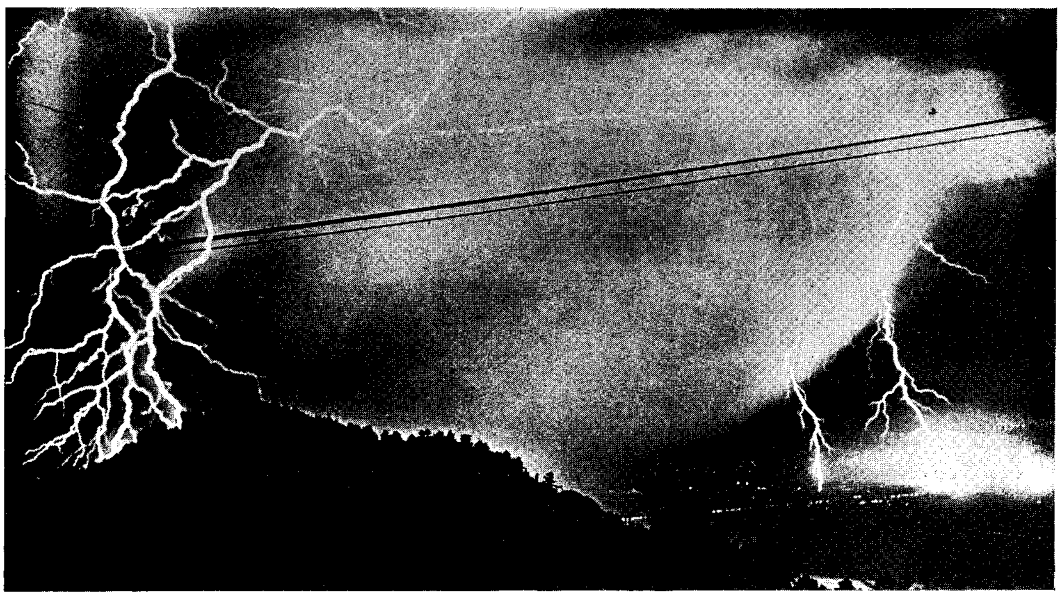
Westinghouse

Electrolytic Lightning Arresters

INSTRUCTION BOOK



Lightning as Photographed From Mt. Wilson Observatory

Westinghouse Electric & Manufacturing Company

East Pittsburgh Works East Pittsburgh, Pa.

I. B. 5127-D

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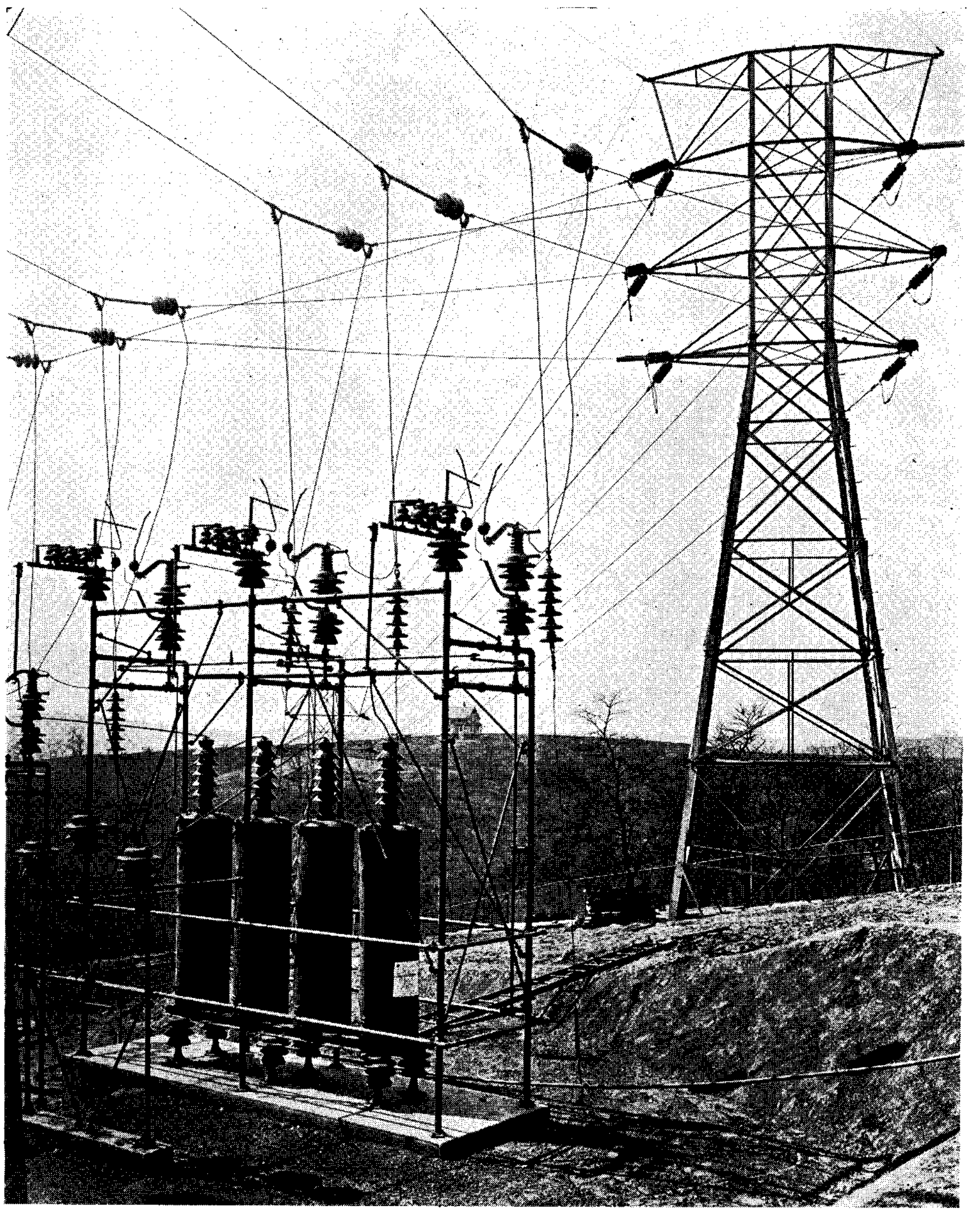


Fig. 1—Type AL Electrolytic Lightning Arrester for 70,000-Volt, Three-Phase Ungrounded Neutral Service. This Shows the Arrester Mounted at the Ground, Just Outside the Station Wall, on a Foundation

Westinghouse

Electrolytic Lightning Arresters

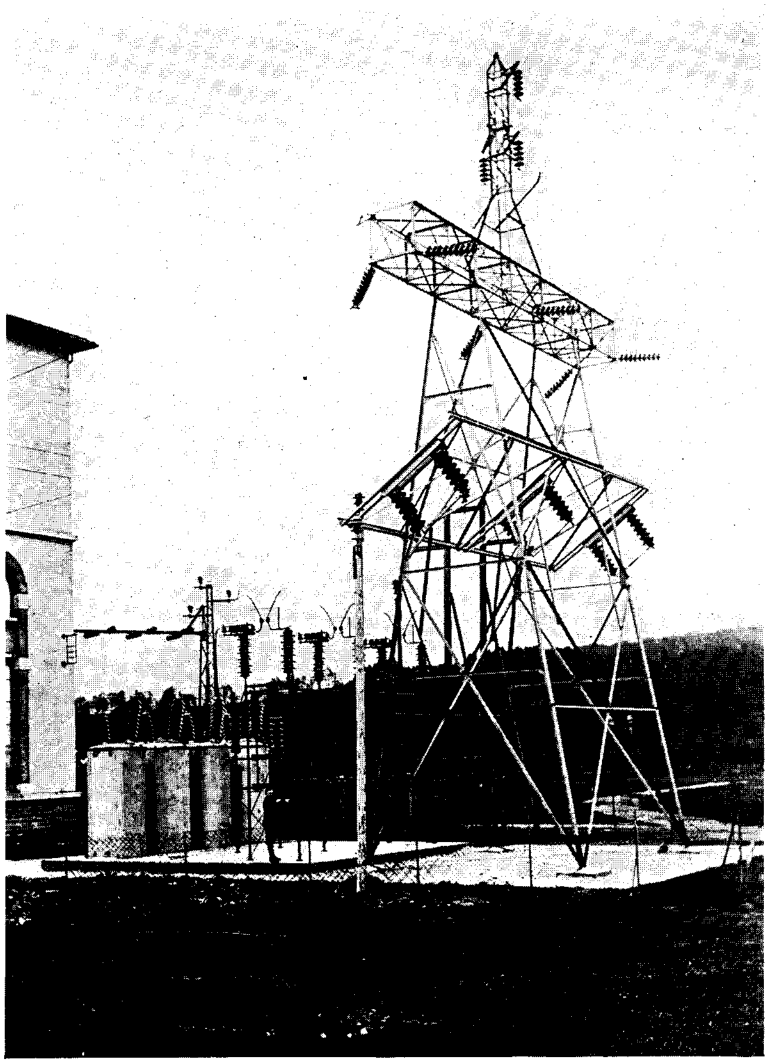


Fig. 2—Arrester Mounted Just Outside Power House

THEORY OF ELECTROLYTIC ARRESTER

1. Essential Properties—There are two essential properties inherent in the electrolytic lightning arrester, and it is due to these important properties that it operates so successfully. They are:

A. The fact that it offers a very high resistance to the flow of current at normal voltages, and a very low resistance to current at abnormal voltages.

B. Its electrostatic capacity, by virtue of which its effective resistance to currents at low (normal) frequencies is great, but to currents at high (abnormal) frequencies small.

These two properties are discussed more in detail in the paragraphs that follow.

2. Comparison With Safety Valve—The electrolytic lightning arrester is ideal because it possesses characteristics analogous to those of a steam safety valve or hydraulic relief valve. Such an appliance permits no escape of steam, or water, at normal pressures, but when the impressed pressure exceeds the normal, the valve opens and the excess pressure is relieved. When the pressure is relieved the ideal relief valve immediately closes and prevents further leakage. In the electrolytic lightning arrester these characteristics are more closely duplicated than in any arrester heretofore developed. It affords instantaneous and ample relief from dangerous abnormal voltage stresses, and when the excessive stress is relieved the action of the arrester immediately prevents further flow of current.

3. Explanation of Action—This vital property of the electrolytic arrester is due to the inherent characteristic of a *film of aluminum hydroxide* which is deposited on an aluminum plate immersed in a suitable electrolyte. Such a film, although it is very thin, has an exceedingly high apparent resistance when moderate voltages are impressed on it, but when the pressure reaches a higher well-established value, known as the critical voltage, the film breaks down in myriads of minute punctures. The critical voltage varies with various electrolytes, but for electrolyte D it is approximately 420 volts for alternating current and 470 volts for direct current. Voltages above the critical point are very nearly short-circuited and the flow of current is retarded only by the resistance of the electrolyte. The discharge current is permitted to pass with a freedom proportional to the superficial area of aluminum plate surface exposed to the electrolyte. When the excessive pressure is relieved and normal pressure restored, the minute punctures at once seal up; the original resistance reasserts itself and no discharge of dynamic follows.

4. As a Condenser—In addition to its property of preventing leakage at low pressures and permitting flow at excessive pressures, an aluminum hydroxide film on an aluminum plate *constitutes the dielectric of an electrostatic condenser.* This property is of considerable importance, inasmuch as the impedance or tendency to retard the flow of alternating current varies inversely as the frequency of the current, the retarding effect of a condenser is relatively small at high frequencies.

5. Effect of Condenser—Currents due to lightning discharges and static disturbances *are of high frequencies* often as high as 500,000 cycles and sometimes much higher. An electrolytic arrester, due to its electrostatic capacity, will, without any appreciable rise in voltage discharge nearly 1000 amperes at a frequency of 100,000 cycles. At commercial frequencies the impedance of an electrolytic arrester is relatively high, but it is still low enough to permit a current of something less than ½ ampere to flow at normal frequencies. To prevent overheating of the arrester by such current, gaps are inserted between the line and the arrester; normally they insulate the arrester from the line, but at excess voltages they arc over and permit a discharge through the arrester which relieves the abnormal stress.

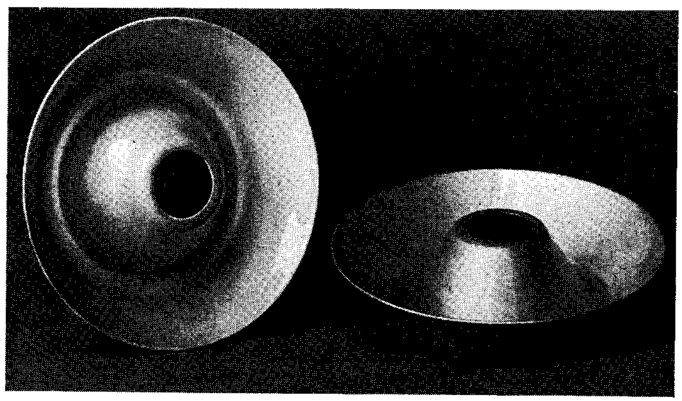


Fig. 3—Aluminum Trays Used in the Electrolytic Arrester

6. Formation of Film—The aluminum hydroxide film is formed on the aluminum trays of the electrolytic arrester by *electrolytic process.* When the trays are shipped to the customer they are ready for immediate installation.

7. Gaps—Three kinds of gaps are used with electrolytic arresters—horn gaps, sphere gaps and impulse gaps. The horn gaps and sphere gaps are supplied with the type AK arresters depending upon the voltage. The impulse gaps give a much greater degree of

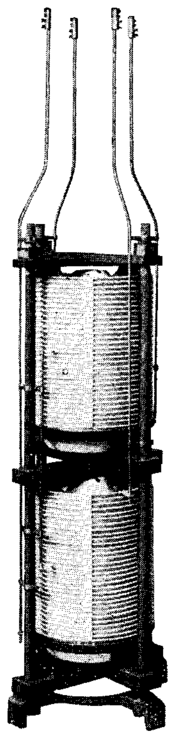


Fig. 4—Design of Tray Structure Used For Voltages Up to 7500

This shows aluminum trays nested in wooden supporting frame for a 66,000-volt underground neutral arrester.

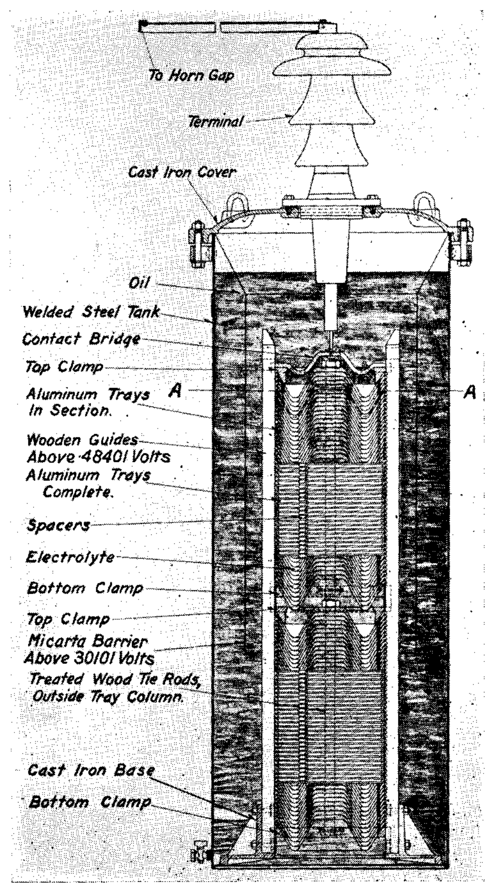


Fig. 5—Section of a Typical Type A Electrolytic Arrester

protection than the horn or the sphere gaps and are supplied with the type AL arresters.

The horn gaps are supplied on the type AK arresters only, for 15,000 volts and less, as the relation of the size of the horn to the gap settings, is such that approximately the same results are obtained as with spheres.

Sphere gaps are supplied on all type AK arresters for voltages of 15,000 volts and up. Before a gap can discharge, there must be built up at the point of the discharge, a sphere of equipotential. This involves a time element. The sphere gap provides this sphere of equipotential and eliminates the time element necessary to built up this sphere of equipotential. This lowers the high-frequency discharge value of the gap, because of the elimination of this time element, the incoming surge does not have time to rise to a high voltage before the gap breaks over. Consequently above certain voltages the sphere gap gives an increased degree of protection over that given by the horn gap.

8. Theory of Impulse Gap—The impulse gap is a device consisting theoretically of a gap shunted by a system of condensers and resistance and with an antennae arranged so that a gap which is set to withstand the normal 25 or 60-cycle voltages on the l'ne will select the disturbances of high frequencies or steep wave fronts sometimes termed impulses, and discharge them to ground at a voltage very much less than the 25 or 60-cycle discharge value of the gap setting. This discharge value can be made as low as 60 per cent of the 25 or 60-cycle discharge voltage of the gap.

The theoretical circuit of the impulse gap is shown in Fig. 7. If we omit the unbalancing resistances, the antennae will always be at a potential midway between the potential of the two horns of the gap, but by placing the resistance in series with the condenser between the line and the antennae, the flow of charging current through the resistances unbalances the potential between the antennae and the two gaps, placing the higher potential between the antennae and the side of the gap to which the resistance is connected. At 25 or 60 cycles the charging current through the condensers is small and consequently the unbalancing at these frequencies is slight, but at high frequencies such as are encountered in lightning

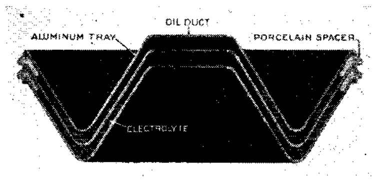


Fig. 6—Cross-Section of Trays, Showing Spaces

disturbances, the condensers permit a considerable amount of charging current to flow, this charging current flowing through the resistance produces a high potential across the resistance and consequently across the gap between the antennae and the horn to which the resistance is connected, which breaks over the gap between the antennae and the horn. The breakdown between the antennae and the horn is facilitated by making the antennae a needle and the main gap between spheres. On

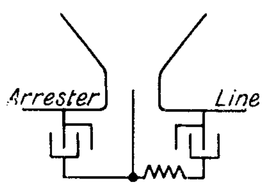


Fig. 7—Theoretical Circuit of Impulse Gap

voltages below 15,000 volts the size of the horns is sufficiently large that spheres are not required, but above that voltage the gap is between the needle and spheres. This arrangement facilitates the discharge of the gap because with a given setting the discharge

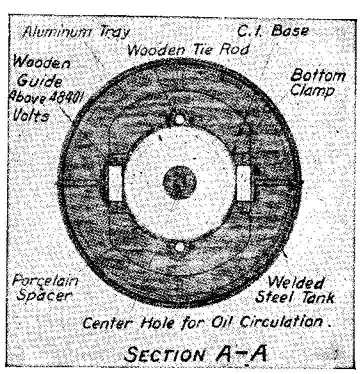


Fig. 8—Cross-Section Through Tank at A-A (Fig. 5)

voltage between them is less than between two spheres or between the spheres and a blunt nosed antennae.

The theoretical diagram for the commercial form of the impulse gap arresters is shown in Fig. 9. The commercial form of the impulse gap is shown in Fig. 10, in which the condensers take the form of Faradoid insulators, numbered 1 and 2. The charging resistance is included as an integral part of all impulse gap arresters. All impulse gap arresters are provided with short-circuiting clips for the gaps.

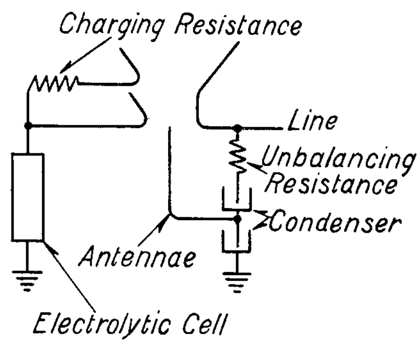


Fig. 9—Diagram for Commercial Form of Impulse Gap Arresters

CONSTRUCTION

9. General Construction—In the commercial electrolytic lightning arrester the aluminum plates referred to in paragraphs 3 to 6 are cone shaped trays as shown in Fig. 3. These aluminum trays are stacked one on another as shown in Fig. 4, each tray being separated from the adjacent trays by porcelain spacers, see Fig. 8, located on its periphery. To give greater ease in handling, the trays on the higher voltage arrester are grouped in sections. The total number of trays in the stack or phase leg is determined by the maximum voltage for which the arrester is rated. There is one tray for each 290 to 325 (effective) volts alternating current, depending on the kind of electrolyte used and the kind of service, and one tray for each 350 volts on direct-current arresters. These stacks of trays are suitably supported in frames of solid construction as shown in Figs. 4 and 11. Each tray is filled with a measured quantity of electrolyte by the customer. The stacks are then arranged in welded sheet steel tanks and the latter carefully filled with oil until the tray structure is entirely covered. A vertical section of an assembled phase leg is shown in Fig. 5. A cross

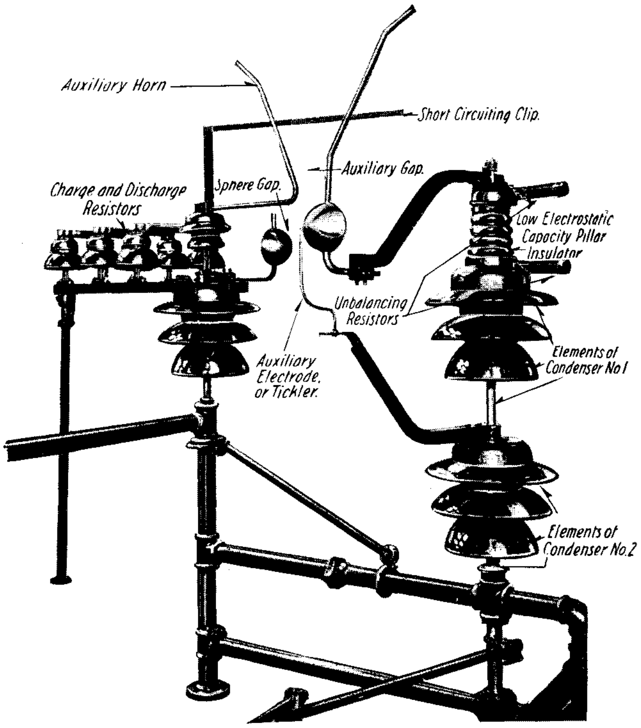


Fig. 10—Commercial Form of Impulse Gap Arresters

section of an assembled arrester in its tank is shown in Fig. 8.

10. Barriers—Barriers or insulating lining inside the tanks are supplied with all arresters for voltage greater than 25,000 volts. These barriers consist of micarta tubes of high insulating properties placed between the trays and the tanks. On these arresters they increase the insulation, thus permitting the use of a smaller tank and a reduced amount of oil. They also increase the oil circulation and thus affect the disposition of heat generated during discharges.

11. Oil—Electrolyte is heavier than oil and therefore remains in the bottom of the trays. The oil serves four purposes, viz.:

1. It improves the insulation between trays.

2. It increases the insulation between the tanks and the trays in all cases when insulation is necessary.

3. It prevents evaporation of the electrolyte.

4. It helps to dispose of the heat caused by lightning discharges by:

(a) Absorbing some of the heat.

(b) Carrying the heat to the steel surface of the tank whence it can be radiated, thus permitting the arrester to discharge continuously for relatively long periods without becoming overheated.

12. Parts—The complete commercial arrester outfit includes, besides the tanks and trays, a supporting structure on which the horn or sphere gap, transfer switch and fuses are mounted.

Insulated racks or tank platforms are furnished with all standard arresters with the following exceptions. All indoor arresters for voltage up to 15,000 volts and the outdoor 7500-volt arresters have grounded tanks. Above 15,000 volts grounded tanks can be furnished at an increased price when specified by the customer. A line of grounded-tank arresters is available for voltages above 73,000 volts.

UNPACKING

13. Unpacking—As soon as practical after receipt of shipment of arresters, the shipment should be checked against the shipping list to see that no parts of the shipment are missing or damaged. By so doing delays can be avoided or reduced in case that boxes

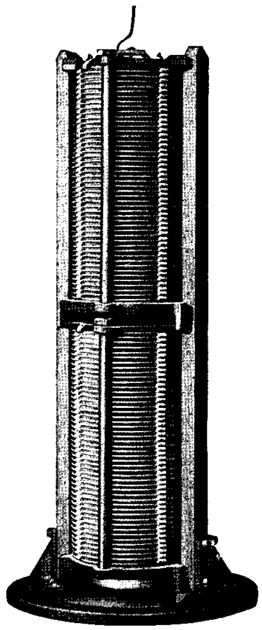


Fig. 11—Tray Sections in Guide

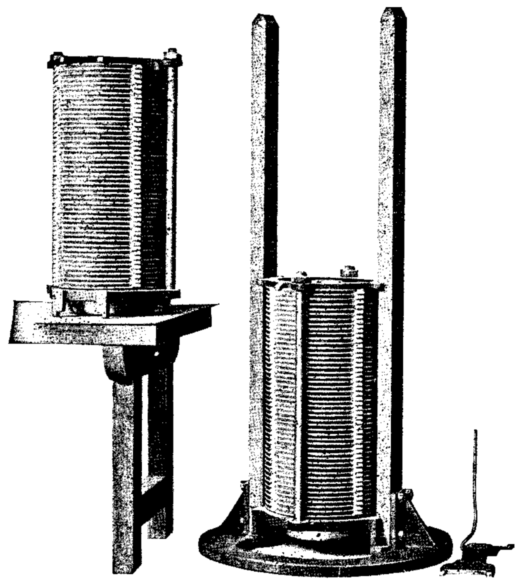


Fig. 12—Tray Sections and Guides
One Section Has Been Removed From The Guides

are missing or damaged. In unpacking this apparatus, great care should be exercised to avoid damaging any portion. The excelsior should be carefully examined to avoid losing or throwing away parts. Carefully inspect insulators to see that they are in good condition. The oil is supplied in cans or drums depending upon the amount necessary for the installation. The electrolyte D is shipped in both the dry and liquid form depending upon conditions and upon the desire of the customer. Carefully note the marking on the electrolyte container. In cold weather the electrolyte should be stored where it will not freeze.

LOCATION

14. Indoor and Outdoor Arresters—The type AK electrolytic lightning arresters for voltages up to 5000 volts are supplied for indoor mounting only. Above 5000 volts they are supplied for either indoor or outdoor mounting subject to the following indications. The type AL arrester is supplied for voltages from 15,000 volts up to 73,000 volts and for either indoor or outdoor service.

15. Considerations Affecting Location—Station arrangement largely affects the actual disposition of any electrolytic arrester installation. It is obvious that as a general proposition the arrester should be erected as near as possible to the equipment to be protected and as *near as possible to the ground connection* (see paragraph 62). An excellent method, where relatively low voltages are involved, is to install the complete equipment —horn gaps and arrester—just inside the station. Type A arresters for voltages below 15,000 volts are designed with this arrangement in view. Their horn gap frames can be mounted on the station wall and the tanks arranged beneath the frame on the floor as shown in Fig. 14.

16. Excessive Temperature—Electrolytic lightning arresters should not be located where they are exposed to excessive temperatures (see paragraph 44). When arresters are mounted near the top of a transformer room or where heated vapors are apt to accumulate, the place should be well ventilated.

17. Outdoor Arrester—For voltages above 15,000 volts it is recommended that the complete arrester equipment be located outdoors; the exception to this is in case of extremes of temperature and in cases when the maximum amount of protection from internal disturbance is necessitated during cold weather. When it is desirable, for the reasons indicated, the horn gap may be mounted outside and the transfer switch and tanks may be located inside the station. If the horn gaps are located outside and the transfer switch inside the station, it is necessary to bring but three wires (for three-phase work) through the wall. If the transfer switch is located outside, it is necessary to bring four wires through the wall to the tanks. For voltages above 35,000 it is necessary that the horn gaps be located outside the station so that the arcs can do no damage. Figs. 2 and 16 show examples of outdoor electrolytic arrester installations

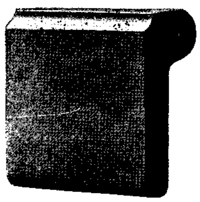


Fig. 13—Tray Spacer

18. Horn Gaps—The horn gaps for all types A, AK, and AL arresters are mounted on steel structures or pipe frames. All indoor arresters for voltages less than 15,000 volts and the outdoor arrester for 7500 volts are mounted on a pipe-framed bracket as shown in figure 14. Indoor arresters 15,000 to 25,000 volts and the outdoor arresters from 7,500 to 73,000 volts have the horn gaps mounted on self-supporting pipe frames. All indoor arresters for voltages greater than 25,000 volts and the outdoor arresters for voltages greater than 73,000 and less than 115,000 volts have the gaps arranged on a short leg pipe-frame structure which is mounted on a supporting structure furnished by the customer. All arresters for voltages greater than 115,000 volts have the gaps arranged on a structural steel base which is mounted on a supporting structure furnished by the customer. Arresters are often mounted on station roofs, an excellent arrangement, in that ample working room about the arrester is usually allowed. In some cases the horn gaps have been mounted on the roof and the tanks inside the stations. Arresters are often mounted on a solid foundation of concrete just outside the station. It is important that the station attendant be able to observe the arcing of the horn gaps during the charging process, (see paragraphs 46 and 47). To this end, operation of the cord, or bell-crank mechanism by means of which the horn gaps are opened or closed, should be possible from a point where the horn gaps can be readily seen. It is desirable to arrange the installation so that the transfer switch, when one is used, can also be operated from the same location.

19. Transfer Switches—The transfer switches on indoor arresters up to 15,000 volts and the outdoor arresters for voltages up to 37,000 volts are mounted on the horn gap and are operated by a hand wheel. On all other alternating-current electrolytic arresters, the transfer switch is mounted on a separate structure which is anchored to the pipe frame or to the foundation and arranged so that it can be operated by a lever arm located a few feet above the floor or supporting base. If the customer so desires a transfer switch can be arranged so that it can be operated by a bevel-gear arrangement or, if preferred, by a chain and sprocket-wheel arrangement, or by a rope and pulley. If the horn gap supporting frame and transfer switch are mounted on the roof, an extension of the operating shafts may be carried directly through the roof into the room below. The switches can then be operated from the room.

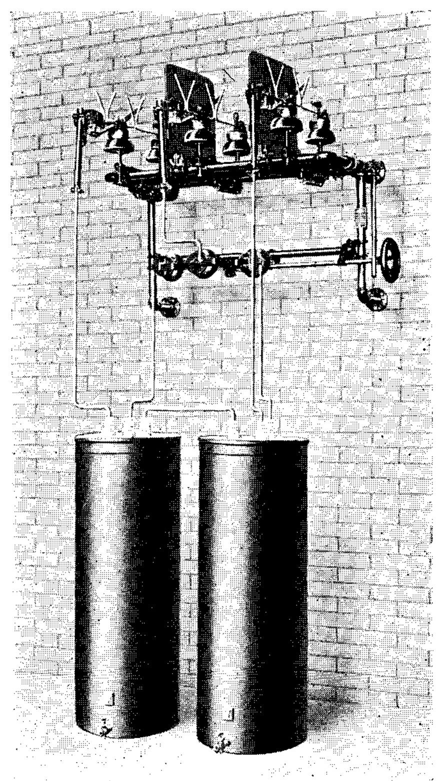


Fig. 14—Type A Electrolytic Lightning Arrester for 9900-12100 Volt, Three-Phase Ungrounded Neutral Service. Tank Grounded. Style No. 231388

20. Horn-Gap Clearance—It is necessary, when installing the horn gaps inside the station—*to allow ample clearances* between them and adjacent members. The following clearances are ample between horn-gaps and non-combustible materials.

Minimum Allowable Clearances Between Horn Gaps and Adjacent Non-Combustible Members	
Up to 7000 volts	30 inches
From 7000 volts to 13500 volts	36 inches
From 13500 volts to 35000 volts	50 inches

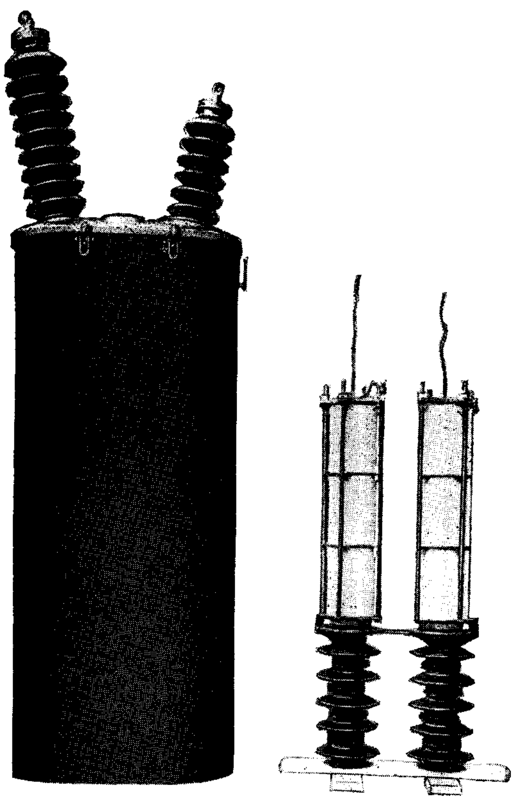


Fig. 15—Phase Leg for 110000 to 115000-Volt Electrolytic Lightning Tank Grounded

Above 35,000 volts, the horn gaps should, in general, never be placed indoors. For outdoor service there should be at least one-foot clearance overhead to conductors for each 5000 volts of line pressure.

21. Special Horn-Gap Clearance—Clearances approximately twice as great as the above should be allowed between horn gaps and combustible materials, or between horn gaps and electrical conductors. As a rule the arc at a horn gap is not of sufficient magnitude to make trouble. But sometimes, because the films have not been properly maintained, the arc is of considerable size.

22. Low Temperature—In outdoor installations the electrolyte may be subjected to freezing temperature for long intervals without being in any way injured by such exposure, but while frozen its conductivity is somewhat low and its protective power correspondingly reduced.

All electrolyte for electrolytic arresters will freeze. Electrolyte D will freeze somewhere between 20 and 26 degrees Fahrenheit. Due to the heat-storage capacity of the oil in the tanks, the electrolyte will not actually freeze unless the cold continues for some little time.

FOUNDATION

23. For all outdoor installations a concrete foundation is desirable. For indoor installations the foundation, see Fig. 1, should be firm, solid, and fully capable of carrying the weight of the arrester. In every case the containing tank should be so placed that the oil drainage valve at the bottom of the tank is accessible and high enough above the foundation to permit a pail to be placed under it to remove oil from tank when necessary, or so it can be connected to the piping of an oil drainage system.

NUMBER OF UNITS

24. Number of Units—The number of tanks given in this paragraph apply to three-phase systems only. Indoor arresters, up to 7500 volts and the 7500-volt outdoor arrester have the electrolytic element arranged in one grounded tank. The 7500 to 15000-volt arresters for indoor service have two grounded tanks. Outdoor arresters for all voltages above 7500 volts and indoor arresters for voltages greater than 15000 volts have four insulated tanks, one for each phase leg and a ground leg.

INSTALLATION

25. Cleanliness—Care—An important point to remember constantly when erecting an electrolytic arrester is that all parts of it must be absolutely clean before it is finally assembled. A very small quantity of dirt in the tanks or trays may prevent proper operation of the arrester and spoil the electrolyte. *The tanks should be thoroughly cleaned.* All chips or dirt should be carefully removed. The tanks should be placed on the foundation in their permanent positions and accurately leveled. The tray element should be carefully examined to see that no adjacent trays are in metallic contact. Such contact sometimes occurs due to rough handling in shipment. All excelsior and dust must be removed. For the higher voltages the total number of trays is divided into sections; each section has its

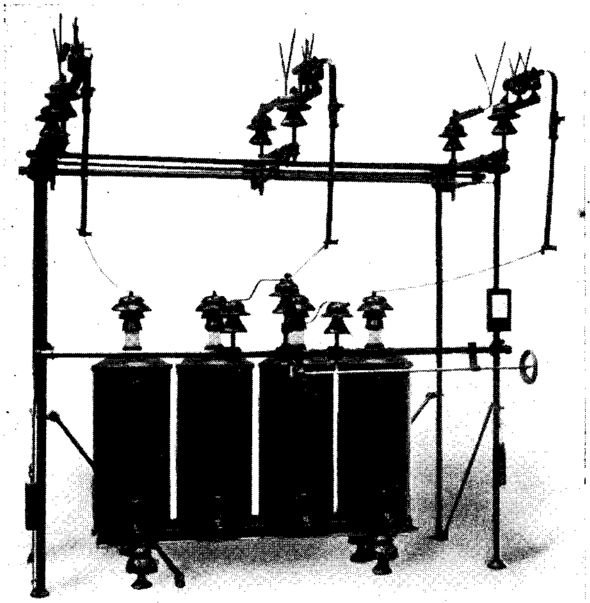


Fig. 16—Electrolytic Lightning Arrester for 18500 to 24700-Volt, Three-Phase Ungrounded Neutral Service for Outdoor Mounting. Style No. 231426

own supporting frame and contains only as many trays as can be handled at one time.

26. Diagrams—An outline blueprint showing the relative positions of all parts of the complete equipment is furnished with each arrester. The print shows diagrams of connections and gives all other necessary information, so that no trouble should be experienced in erecting the apparatus. Special care should be taken to provide the clearance between insulated tanks and grounded frames that are shown on drawings.

27. Preparing Trays—The various sections composing the tray elements should be assembled to ascertain if they fit properly together. The tray should be filled with electrolyte as described below, before the sections are deposited in the tanks. No tray should be filled with electrolyte until the arrester can be immediately placed in service on the line. If the electrolyte is allowed to stand in the trays for longer than two days, it will dissolve the film and "reforming" will be necessary before the arrester is finally placed in service.

28. Electrolyte—*Absolute cleanliness* must be maintained *while handling electrolyte.* It and the trays *must be kept free from dust.* If the electrolyte becomes slightly impure an excessive current will flow when the arrester is being charged and the trays will wear out rapidly. If a large amount of impurities be present in the electrolyte the current at charging will be very large and the arrester will not operate satisfactorily.

29. Filling Trays—Each section should be filled with electrolyte as shown in Fig. 17 so that tray is in *good contact* through the medium of the electrolyte, with the two adjacent trays. The electrolyte should be poured into the trays from measuring cup Style No. 125412 (Fig. 18), one of which is furnished with each installation. This cup holds the proper amount of electrolyte for one tray.

30. A small **marker** of cardboard or wire should be used, as shown in Fig. 17, to check off trays as they are filled, and great precaution must be exercised to see that every tray contains its full measure of electrolyte.

31. Testing of Trays—The trays should not be filled with electrolyte until everything is in readiness to place them on the line. After the stack of trays has been filled with electrolyte it is desirable that they be tested to see that they have been properly filled, and given a preliminary charge. This may be done by connecting approximately 250 volts alternating current across the cells successively (a cell consists of two trays with electrolyte between them) with a bank of lamps in series. The number of lamps in the bank should be sufficient to limit the current to 2 amperes with the cell left out. This bank may be made up of any series-paralleled combination that will give 2 amperes across the 250-volt circuit when burning at normal brightness. If the film on the trays is not properly formed, the lamps will burn brightly at first, but will become dim as the film builds up. Care should be taken not to allow the electrolyte to become warm. If the lamps do not burn brightly at first the films are properly formed,

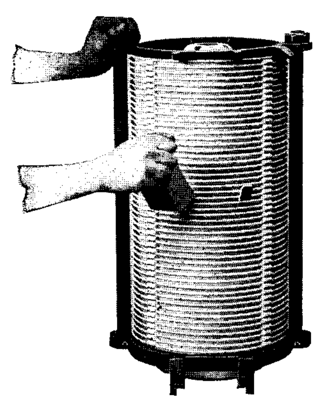


Fig. 17—Tray Section for More Than 13500 Volts. Shows Method of Filling Trays With Measuring Cup and Use of a Marker

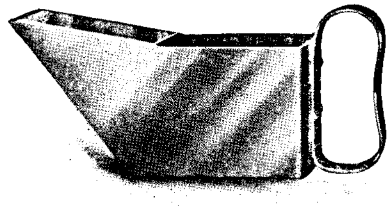


Fig. 18—Measuring Cup For Filling Trays, Style No. 125412

but if the lamps do not burn at all the tray is not filled with electrolyte. If 250 volts alternating current is not available, 500 volts may be used across two cells in series, thus adding 250 volts for each additional cell in series. If only 125 volts is available for this purpose, an indication as to whether the trays are filled or not may be obtained, but the film on the trays will not be fully formed. If only direct current is available this may be used, but in each case the leads should be reversed and the operation repeated.

(See Fig. 18-A.)

32. Putting Trays in Place—After filling each section with electrolyte, it should be lowered into place, care being taken to see that the bottom section is properly resting on the casting at the bottom of the tank. Great care should be exercised not to spill the electrolyte from the trays, since failure of any one tray to be in contact with the two adjacent ones, through the medium of the electrolyte, will render that phase leg inoperative.

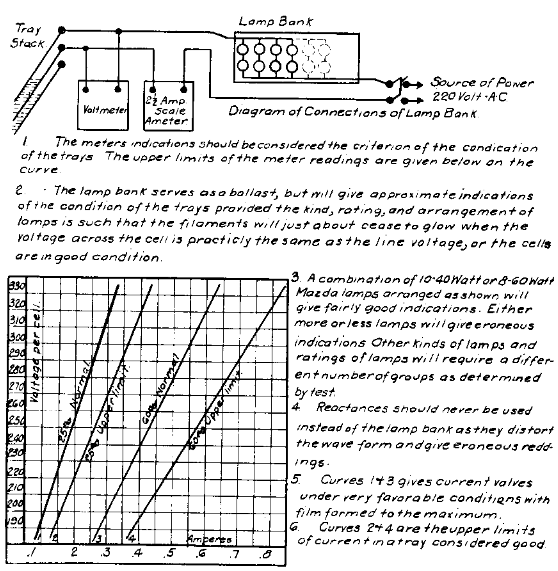


Fig. 18-A—Testing of Trays (See Paragraph 31)

33. Filtering of Oil—The oil, inasmuch as it frequently contains fragments of iron scale, should be filtered before being placed in the tank. A filter can be conveniently made by covering the top of a large funnel with two layers of ordinary finely-woven cotton cambric that has been thoroughly washed and dried to remove sizing. This will remove dirt or other matter held in suspension.

34. Inserting Oil—When the filled trays are in position, the *oil should be carefully poured, syphoned, or pumped* slowly into the tank. Avoid splashing it into the trays. The oil can be easily introduced properly by pouring it downward against the inside of the tank so that it will flow to the bottom without striking any trays. The electrolyte, which is but slightly heavier than the oil, will be washed from the trays unless care is taken. The tank should be filled with oil to within a few inches of the top, so that the trays and electrolyte are submerged in oil.

35. Covers—The covers of the tanks *should not be clamped down tight.* It is better for the apparatus if some circulation of air is allowed.

36. Horn Gaps—The arresters are provided on the line side with horn gaps so adjusted that they will withstand the operating voltage of the system under normal conditions and prevent the flow of charging current, but will allow abnormal voltages due to lightning, surges, grounds, or other causes to discharge through the electrolytic units. By means of the table of horn gap settings the gaps can be adjusted for any line voltage.

37. Setting Horn Gaps—It should be understood that a *definite horn-gap setting* for any given voltage *cannot be definitely recommended* because they are several factors (see paragraph 38) which must be considered before the best gap-setting can be determined. In the table of horn-gap settings a maximum and minimum setting is given for each voltage. These values have been compiled after a thorough consideration of the settings that have provided good protection in actual practice. Unless information obtained through experience with horn gaps operating under precisely similar conditions is available, it is good practice to initially set the gap with the greatest separation shown in the table. The separation can then be decreased by adjusting the stop, say a small fraction of an inch a day, until the jumping distance is so small that arcing occurs at times of load changes or of switching. The separation should then be increased again until there is no arcing at times of normal static disturbances. The *minimum setting given in the table is the smallest that can be safely employed* for the voltage shown.

38. Factors Affecting Horn-Gap Settings—Four important factors that affect the horn-gap setting may be tabulated as follows:

(a) **The density of the surrounding atmosphere.** It has been demonstrated both by experiment and in practice that an arc will jump farther in a rarified atmosphere than in a dense one. Therefore horn gaps must be set, all other things being equal, farther apart, in a high altitude than in a low one.

(b) **Inherent characteristics of the circuit.** The inductance and capacity of a circuit, which controls its tendency to resonance, affect the calibration. Where there is a tendency to resonance the gap is jumped more readily. In cases of this kind the cause of the tendency should be removed; or if this is impossible the horn gaps must be set farther apart.

(c) **The wave form of the impressed voltage.** It is the peak value of voltage which determines the length of the spark gap, and not the effective voltage. Therefore on lines where the voltage wave is peaked, the horn gaps must be, other things being equal, set farther apart than on a line of the same voltage where the wave is smoother.

(d) **The nearness of grounded object to the horn gap.** The presence of grounded or metal objects near the gap changes the potential gradient between the horns and therefore affects the sparking distance. The presence of such objects may either increase or decrease the tendency to spark over. The effect depends on several conditions. In any case, in actual installations, the effect due to this cause will be very small, if not altogether negligible.

39. Fuses—It is often desirable to set the gaps so that they will discharge in case a ground on one leg occurs. To prevent such a discharge, which might be very heavy, from continuing indefinitely, fuses are inserted which protect the arrester, but in no way reduce its effectiveness.

40. Bridging of Horn Gaps—The horn gaps are so arranged that they can be easily bridged in order to **rebuild the film** (see paragraphs 41 to 49), and so that fuses and arresters can be disconnected from the line when desired.

41. Method of Bridging Horn Gaps—On all arresters one gap is stationary, and one gap is movable. The indoor arresters for voltages up to 15,000 volts and a 7,500-volt outdoor arrester have the short-circuiting clip located on the cap holding the stationary horn. When the two gaps are in the operating or in normal position, the horns are in the same plane and the horn adjustment is obtained by loosening the set screws and pushing the horn in or out as may be necessary. On these arresters the horns are held in position by notching fingers arranged on an extension of the pipe which connects the gaps so that they swing in unison. These fingers engage the supporting pipe at the end of the frame and hold the horns in their proper relation. To charge the arrester the connecting pipe is rotated until the fingers are disengaged, then the swinging horn is rotated until it comes in contact with the short-circuiting clip. To open the gaps the swinging horn is rotated in the opposite direction until it is in the open position and when the lever arm is released, the weight of the arm again causes the fingers to be engaged with the supporting pipe. On all other arresters the short-circuiting clip is mounted on the swinging arm. A pin holds the operating lever in the various positions by engaging corresponding holes on the plate over which the lever arm moves. This pin is attached to the arrester by means of a chain. When it is desired to charge the arrester lever is moved so the movable horn swings out of alignment until the swinging horn comes in contact with the short-circuiting clip, and to open the horn gap, the swing horn is moved in the opposite directions until the operating arm is in the open positions when the arm is held by the pin described above.

With the horns thus open, the length of gap is ample to permit working on the apparatus with safety. On outdoor arresters for 10,000 volts or over, the fuses are on the arrester side of the gaps so that fuse tongs are not necessary for handling them.

42. Charging Resistance—When electrolytic lightning arresters are charged, high frequency ripples are set up in the charging circuit. These ripples are due to the inherent capacity of the arrester and characteristics of the line. Ordinarily, these ripples are of small value and are harmless, but under certain conditions it is necessary to make use of some device to damp them out. This device is called a charging resistance and the essential part is a resistance which is introduced into the circuit at the time of charging the arrester and at the end of a lightning discharge.

The settings for the sphere gap, horn gap, and auxiliary gap, given in tables on pages 23 to 25 are approximate, due to the effect local conditions may have on the gap settings. The settings given are the limits of those usually found to give the most satisfactory service, but ultimate purchaser may desire to vary the settings to meet his own particular and peculiar operating conditions.

The charging resistance consists of resistance rods shunted by either one or two horn gaps and arranged as an attachment which can be mounted on the stationary horn gaps (see Fig. 14) one unit being required for each horn gap (for diagrams see page 22). Charging resistances are furnished on all type AK arresters. They are necessary in the following cases and do no harm in any case.

(a) On all electrolytic arresters which are used for the protection of cable systems. This is because of the low inductance and high electrostatic capacity when compared with overhead systems. This construction tends to increase or magnify the voltage of the ripples. (**Note—Choke coils should not be used in connection with arresters on cable systems.**)

(b) On all arresters which are used for the protection of motors and generators which are connected directly to the line without the intervention of transformers. This is because motors and generators have when compared with transformers, comparatively weak insulation on the end turns.

(c) In all arresters which are used for the protection of transformers which are known to have weak insulation on the end turns.

For setting of horn gaps on charging resistance see tables on pages 23 to 25.

OPERATION AND CARE

43. Disintegration of Film—Charging—There is a tendency on the part of the films on the aluminum trays to disintegrate when the trays are allowed to remain indefinitely in the electrolyte with no electromotive force impressed across them. If an electrolytic arrester that has stood for some time without being connected to the circuit is reconnected, there is, due to the fact that its film has partly dissolved, a sudden rush of current through the arrester. If the arrester is connected daily to the line the film is maintained in good condition and the rush of current will be harmless in magnitude. However, if the arrester has been disconnected for a long period there may be a troublesome rush of current.

44. Effect on High Temperature—There is a tendency for the films on the trays to disintegrate more rapidly when the electrolyte is at high temperature; this disintegration makes the charging operation more necessary in warm than in cold weather.

Electrolyte D will operate up to 135 degrees with daily charging and for short periods at a somewhat higher temperature. The longer the trays remain in electrolyte without being charged and the higher the temperature, the greater will be the dissolution of the film, and the greater the rush of current when the arrester is charged. In very hot climates it is necessary to protect the tanks from the direct rays of the sun to prevent the premature dissolution of the film which takes place if the tanks become very warm.

45. Neglecting to Charge—As before stated it is necessary to bridge the horn gaps every day in order to maintain the film, as it partly dissolves in case no discharge takes place. The neglect of this duty at the prescribed intervals, which takes no longer than 30 seconds, *will lead to a heavy momentary power current* following any discharge which may take place, for in each case there is only a partial film present to prevent flow of dynamic current. The dynamic current builds up the film; but, in spite of this, the momentary flow may be so great as to blow the fuses or open the circuit-breakers at the nearest station.

46. Method of Charging—In charging the arrester the horn gap should be swung to the charging position and held there about five seconds and then opened. This may be repeated two or three times, but in no case should the horns be swung back and forth into the charging position, as this tends to set up surges on the line.

47. Charging Ground Leg—In order to maintain the best condition of the film on the trays of the ground leg of an arrester used on ungrounded systems it is necessary to *interchange the ground leg* with one of the phase legs every time the horns are bridged, as when the circuit is in a normal condition there is no appreciable pressure across the ground leg even during charging.

48. Use of Transfer Switch—To impress line voltage across the ground leg of the arrester it is only necessary to reverse the transfer switch, which connects the ground leg across the line. The transfer switch may be left in either position, as both of the arrester units to which it connects are of exactly the same construction. It is a good plan to charge and then reverse the position of the switch and then charge again at each time of rebuilding and so leave the switch until the next charging operation, so that the rebuilding of the grounded leg will always be assured. This interchange of leads is required on grounded neutral arresters only, the horns being bridged both before and after it is done.

49. Effect of Freezing—Electrolyte freezes between 20 and 25 degrees Fahrenheit if long continued, but it takes considerable time for the cold to penetrate the jacket of oil around the tray column. Electrolyte may be subjected to freezing temperatures for long intervals without being injured in any way, but while frozen its conductivity is low, its freedom of discharge is materially reduced, and its protective power is correspondingly reduced but returns when it thaws.

50. Building Film—When initially putting the arrester into service, after making sure all is in working order, it is advisable to bridge the horn gaps once or twice to completely form the film. If, before placing them in service, the cells have remained unconnected for a period longer than two days, or if, having once been in service, twice the normal charging period has elapsed without the arrester having been charged, it is not best to impress at once full line pressure across them. In such cases the films should be reformed by either one of the following methods:

(a) Arcs should be started between the horn gaps, with about one-half normal line voltage impressed across them. The gaps should then at once be opened. This operation should be repeated 10 or 15 times just as in the normal periodical chargings described in paragraph 41. The impressed pressure should then be raised to three-fourths normal and momentary discharges across the gap should again be caused to jump 10 or 15 times. Now normal line voltage can be impressed across the arrester and momentary arcs started across the horn gaps as above.

(b) Often it is not possible to obtain the proper reduced voltages. In such cases place in series between the horn gaps and the tanks, instead of the ordinary fuses, a fuse of No. 30 copper wire or a single strand taken from a lamp cord, and bridge the gaps as in normal periodical charging. The fuses will be blown each time the horn gaps are bridged until the films have reached the normal operating condition. Repeat this operation 15 or 20 times, replacing the fuses as they are blown until the fuses are no longer blown when the gaps are bridged, and the normal condition is indicated by a bluish crackling spark (paragraph 52).

(c) In many cases it will be found convenient to build up the film on the trays by the method outlined in paragraph 29 for testing trays. In cases when it has been necessary to dismantle the tray structure and rebuild it, this method is preferable.

In cases when the film has been allowed to deteriorate to a very low point it may be found that at first the film is not readily built up. Experience has shown, however, that the film may be built up by persistent efforts, if the electrolyte is pure or in fair condition.

51. Care in Building Up Film—In cases where the film is being built up from a very low point, the electrolyte is liable to become quite warm. And it is advisable not to build the film up to the maximum point at one operation, but instead, to divide the complete operation into several periods with intervals of time of about ½ hour or thereabouts to allow the electrolyte to become cool again. When films have been built from a low point up to normal as just described and the arrester has been placed in operation, it is also advisable for the first day to charge the arrester at intervals of a few hours or until the electrolyte has reached the normal temperature.

52. Indication of Condition—By bridging the horn gaps, as explained above, several times in succession, a reliable indication of the condition of the arrester is obtained. If a heavy, fluffy, reddish, power arc is maintained, which rises high on the horns it shows that the arrester is in bad condition and the film has not formed. If all plates are not in contact through the medium of the electrolyte, or its oil has run into the space between them due to their not having been filled with electrolyte, there will be very little spark, if any, when the horn gaps are bridged. The *normal condition* of the arrester is *indicated by a bluish, crackling, static spark* which tends to die out and which does not rise high in the horn gap.

53. Indications of Bad Condition—A *rumbling sound in the tanks* during charging operation is caused by an arc jumping between trays. As a rule this is caused by a tray not being sufficiently full of electrolyte. If the rumbling is heard, the trays should be withdrawn and carefully examined. If no dynamic arc appears at the horn gaps when they are bridged and there is only a *feeble spark*, it is an indication of an open circuit in the arrester. Probably some tray was left unfilled and the impressed voltage is not sufficient to start an arc through the oil.

54. Deterioration of Trays—There is normally no appreciable deterioration of the trays, but there is a slight tendency for trays to lose their electrolyte slowly, especially those trays which are near the top. During long heavy discharges or when there is a heavy rush of current due to insufficient charging, the oil becomes heated and rises to the top, heating the upper trays more than the lower ones. The heavy discharge or rush of current may form bubbles on the surface of the trays that are warmest and have least electrolyte. When the arresters are in good condition these bubbles are small and readily escape, but when some time has elapsed without charging or the electrolyte has been in service for a year or more, the bubbles may be large enough to cause an arc which short-circuits the tray, causing puncture. If the arresters are new or are in good condition there is very little danger of this trouble, but as the electrolyte becomes older the distribution is apt to be unequal and the danger of punctures increases.

55. Inspections—An arrester should be watched and inspected at frequent intervals to ascertain its condition, especially after one year of service. It is recommended that the arrester be carefully examined at least once a year, preferably just before the lightning season. If there is any indication that it is not in good condition, it should be overhauled, the trays should be cleaned by washing with gasoline or good soap (Ivory soap is good for this purpose). If soap is used it should be entirely washed off. All trays that are not in first-class condition should be replaced. The trays should be filled with new electrolyte, but *it is not necessary to supply new oil.*

55-A. Rebuilding of Tray Columns: When reassembling the tray stacks it is essential that the spacers be placed over the pads on the lower castings and over each other in a straight line so as not to bevel the trays out of shape. Fig. 19 shows a device which greatly facilitates the assembling of the tray stacks in the correct manner.

56. Records—It is essential to the successful operation of the arrester that it be charged regularly at the specified intervals. In view of this it is recommended that the charging of electrolytic arresters be made a part of the regular daily station routine. *A record should be kept* on the station log of

(a) The time of charging.
(b) The size of the arc.
(c) The color of the arc.

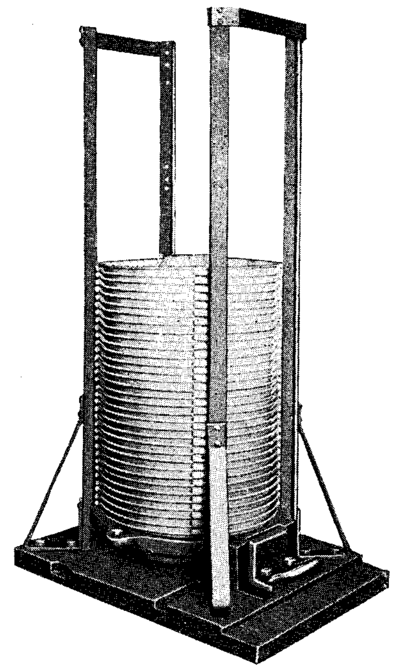


Fig. 19

(d) The height to which it rises on the horns.

Not only is a systematic routine on charging valuable from the record that it affords, but it tends to familiarize the operators with the operation of the arrester and to increase their interest in it.

57. Action of Hot Electrolyte—Hot electrolyte dissolves the film on the trays much more readily than does cool electrolyte. Caution should therefore be exercised when an arrester that has been heated by a severe discharge is charged for the first time after the discharge. In such cases it is best to treat the arrester as if it had never been in service and impress on it first but a fraction of the line pressure as indicated in paragraph 48.

PRECAUTION

58. Railing—Arrester tanks insulated from the ground should be surrounded by a railing or other suitable protection to prevent anyone from coming into accidental contact with any part of the arrester while in service. Any such contact during periods of discharge would be extremely dangerous.

GROUND CONNECTION

59. Importance of Good Ground—Too much importance cannot be attached to the making of proper ground connections. These should be as short and straight as possible. A poor contact will render ineffective every effort made with choke coils and lightning arresters to divert the static electricity into the earth. It is important, therefore, not only to construct a good ground, but in doing so to appreciate thoroughly the necessity of avoiding unfavorable natural conditions. Many lightning arrester troubles are traceable directly to poor ground connections.

60. Connection to Existing Grounds—Direct connection to an underground pipe system (such as a city water main), furnishes excellent ground, because of the great surface of pipe in contact with the moist earth and the maximum number of alternative paths for the discharge. A supplementary ground line should always be connected to the structural steel frame work of the station, and to any nearby trolley rails.

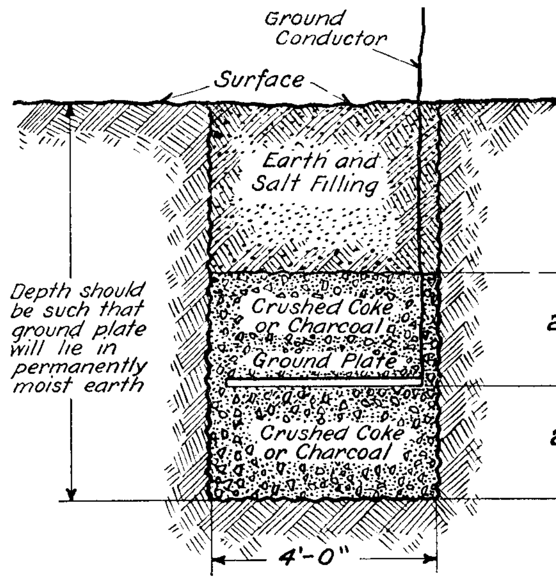


Fig. 22—Method of Making Ground Connection

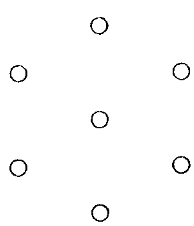


Fig. 20—Arrangement of Multiple Pipe Ground

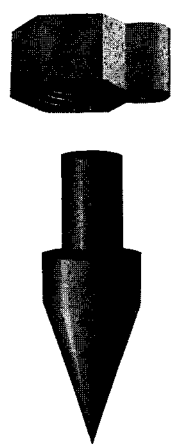


Fig. 21—Ground Point and Cap

61. Methods for Making Lightning Arrester Grounds—

(a) **Buried Plate**—A good ground connection for a bank of station arresters may be made as detailed in Fig. 22, in the following manner:

First, dig a hole four feet square as near the arrester as possible until permanently damp earth has been reached.

Second, cover the bottom of this hole to a depth of two feet with crushed coke or charcoal (about pea size).

Third, over this lay 10 square feet of tinned copper plate.

Fourth, solder or rivet the ground wire, preferably No. 0 copper, securely across the entire length of the ground plate.

Fifth, cover the ground with two feet of crushed coke or charcoal, and

Sixth, fill the hole with earth, *with plenty of common salt* sprinkled in it, using running water to settle it.

The method above given of making a ground connection is simple and has been found to give excellent results; and yet if not made in proper soil it will prove of little value.

(b) **Iron Pipe Ground**—A ground that is simple and very effective may be obtained by driving galvanized-iron pipe into the earth. These pipes should each have a galvanized-iron point and a brass cap with a lug for soldering, (see Fig. 21), malleable point, Style No. 157169 and brass cap Style No. 157170. Three-fourths-inch pipe is sufficiently large for this purpose. The pipes should be 8 to 10 feet long and should be driven into the earth until about 6 inches is exposed. For station arresters a multiple-pipe ground should be used, the pipes spaced approximately 8 to 10 feet apart. An arrangement of 7 pipes in parallel is very good for this purpose; they may be arranged as shown in Fig. 20, an arrangement which is economical in space and wire. A single-pipe ground or any pipe of a group should have a resistance to an adjacent water pipe of not more than 15 to 30 ohms; two pipes in parallel not more than 7½ to 15 ohms; three pipes in parallel not more than 5 to 10 ohms; etc.

Sprinkle plenty of salt on the surface of the earth about points when pipes are driven. Sea water when available is admirably adapted for keeping the ground damp.

(c) An excellent and conveniently made ground may be effected by utilization of a large old iron casting, fitted with a riveted copper strap and buried in damp earth. A few pounds of *common salt* thrown around the ground terminal (before covering) *helps to maintain a moist condition of the soil.*

(d) Other methods of making grounds may be mentioned. A good one can be made by unlaying the strands of a 500000 circular mill copper cable for one foot or more from the end, and spreading the ends of the strands to form a flat circle. This end is then buried as prescribed for the copper plate. *Wrought iron pipes* driven deep in moist earth, and heavy copper ribbon so disposed and laid in coke or charcoal as to give a surface corresponding to the copper plate *have been used with good results,* but the necessity for locating in damp soil applies in each instance.

62. Proper Soil for Ground—The above method for making a ground connection is simple and cheap and has been found to be very effective; yet if it is not made in proper soil it will prove of little value. Clay, even when wet, rock, sand, gravel, dry earth, and pure water are not suitable materials in which to place a lightning-arrester ground. Rich soil is the best. This soil should be damp and should contain some solution of acid, alkali, or salt; salt water is very excellent for this purpose. When pipe grounds are driven, salt water should be poured around the pipes. Sea water, when available, is admirably adapted for this purpose.

To replace the salt solution washed out of the soil, sprinkle plenty of crystal salt or common salt around the pipe, or better yet place it in moist earth around the pipes just beneath the surface.

63. Grounding in Streams—When a mountain stream is conveniently near it is not uncommon to throw the ground plate into the stream. The practice *results in poor contact,* owing to the high resistance of pure water and the rocky bottom of the stream.

64. Ground Conductor—For the conductor between the arrester and the ground connection, either strap copper or copper tubing should be used. It is important that a conductor having the *greatest possible superficial area* be used, inasmuch as high frequency discharges are carried almost wholly on the surface of their conductor. Strap copper having a section say $\frac{1}{32}$ inch by 1½ inches makes a good conductor for the average condition. Such a ground conductor may be fastened directly to the station structure with wood-screws. The course of the ground conductor *should be direct and have few turns,* the fewer the better.

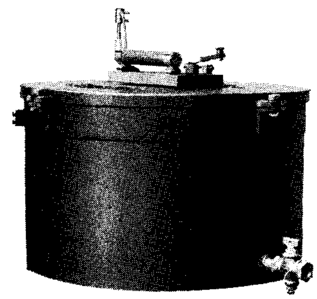


Fig. 23—Type A Electrolytic Lightning Arrester for 500 to 600 Volts, Direct-Current

65. Record of Ground—When an earth connection is arranged it is an excellent plan to make an accurate record of its location, construction, and condition, so that later it may be easily got at for inspection. Earth connections or "grounds" should be periodically examined, and tested for resistance at least once a year to ascertain their condition.

66. Inspection—The ground connection should be inspected from time to time and the resistance and earth connection tested for open circuits.

DIRECT-CURRENT ELECTROLYTIC ARRESTERS

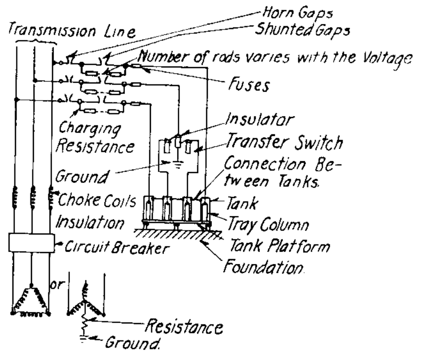
67. The direct-current electrolytic arrester operates on the same principle as the alternating-current arrester. Its construction is very similar to that used on the low-voltage alternating-current arresters. It consists essentially of a small nest of trays in a welded steel tank and immersed in oil. A suitable fuse and a small gap provided with short-circuiting device for charging purposes are placed in series with the nest of trays. This fuse and gap are arranged on a base and mounted on top of the cover.

68. This arrester is designed for indoor station use only. Paragraphs 23 to 33 inclusive, which apply to the alternating-current arrester also apply to the direct-current arrester. The electrolyte for this arrester is usually furnished in 8-ounce bottles. Each (a bottle filled with electrolyte is known as Style No. 141539) bottle contains sufficient electrolyte to fill one tray; all trays except the upper one should be filled with electrolyte. When the trays have been filled, follow closely paragraphs 29 to 32. Before placing in operation, the arrester should be placed thoroughly, charged to make sure it is in good condition. A normal or good condition of the arrester is indicated by a very small bluish crackling spark when the charging device switch is opened.

69. A fluffy reddish power arc indicates that the arrester should be overhauled, the trays cleaned, worn, punctured or damaged trays replaced, and even new electrolyte put in the trays and the arrester thoroughly charged. Sometimes the customer desires to obtain slightly greater protection by closing the gap and placing the arrester directly on the line; in such cases the arrester should be overhauled and new trays installed every 5 months. To obtain the best results it is desirable that the trays be cleaned and new electrolyte put in the trays at the beginning and the middle of the lightning season. The gap should ordinarily be used, as a much longer tray life is obtained and in this case they should be overhauled the same as in the case of the alternating-current arresters. The arresters should be charged daily; this may be done by closing the gap on the top of the arrester.

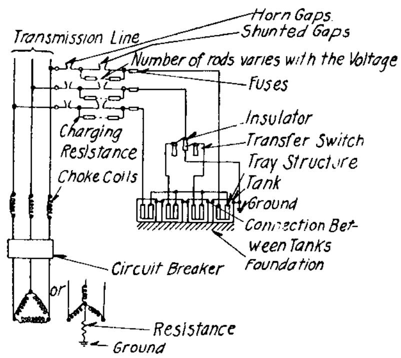
For Diagrams of Connections
and Gap Settings see the
following pages.

DIAGRAMS OF CONNECTIONS



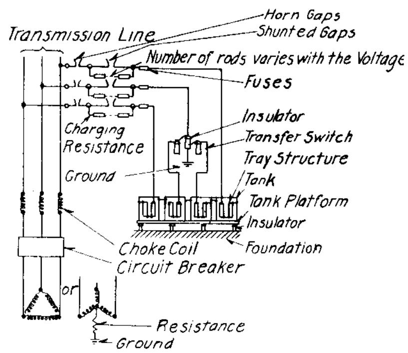
Type AK Arresters 3 Phase.
Grounded or Ungrounded Neutral
Indoor Service 15000 to 25000 Volts.
Outdoor Service 15000 to 115000 Volts

Fig. 24



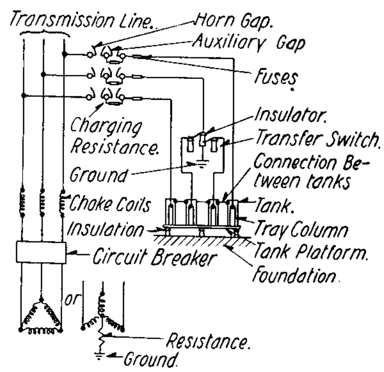
Type AK Arresters 3 Phase
Grounded or Ungrounded Neutral
With Grounded Tanks
73000 to 165000 Volts

Fig. 25



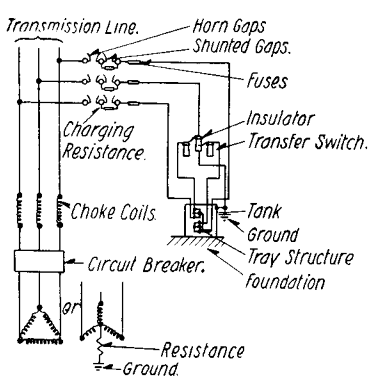
Type AK Arresters 3 Phase
Grounded or Ungrounded Neutral
With Oval Ungrounded Tanks.
73000 to 165000 Volts.

Fig. 26



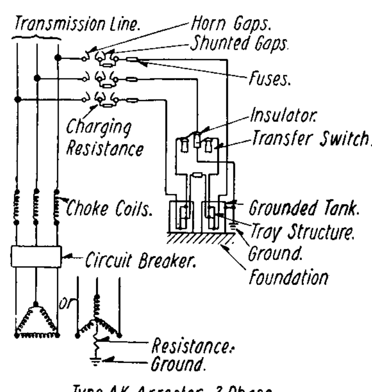
Type AK Arrester 3 Phase.
Grounded or Ungrounded Neutral
Outdoor Service 7500 to 15000 Volts.

Fig. 27



Type AK Arrester 3 Phase
Grounded or Ungrounded Neutral
Grounded Tank Indoor and Outdoor
Up to 7500 Volts.

Fig. 28



Type AK Arrester - 3 Phase
Grounded or Ungrounded Neutral
Grounded Tank Indoor Only
7500 to 15000 Volts

Fig. 29

IMPULSE GAP SETTINGS

NOTE

For a given voltage the low settings go together and the high settings go together. Gap C should be maintained at about 60 per cent of the setting for Gap A.

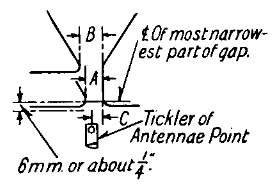


Fig. 30

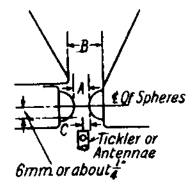


Fig. 31

Indoor—3/8-Inch Horns (See Fig. 30)

Voltage	Range in Millimeters						Range in Inches					
	A		B		C		A		B		C	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
5000	2.1	3.0	3.5	5.5	1.3	1.8	3/32	1/8	9/64	7/32	3/64	5/64
6600	2.8	3.8	4.5	6.	1.7	2.3	7/64	5/32	3/16	15/64	5/64	3/32
7200	3.1	4.2	5.5	8.5	1.8	2.5	1/8	11/64	7/32	11/32	5/64	7/64
10000	4.3	5.9	7.	10.5	2.6	3.5	11/64	15/64	9/32	27/64	7/64	1/8
11000	4.7	6.5	8.5	13.5	2.9	3.9	3/16	17/64	11/32	17/32	7/64	5/32
13200	5.6	7.9	10.	19.	3.4	4.7	7/32	5/16	25/64	3/4	9/64	3/16
15000	6.4	10.2	11.5	24.	3.8	6.0	1/4	13/32	29/64	15/16	5/32	15/64

Table 1

Indoor—62.5—Millimeter Spheres (See Fig. 31)

Voltage	Range in Millimeters						Range in Inches					
	A		B		C		A		B		C	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
10000	4.	5.5	5.	6.	2.4	3.3	5/32	7/32	13/64	15/64	3/32	9/64
11000	4.5	6.1	5.5	6.5	2.7	3.7	3/16	1/4	7/32	17/64	7/64	5/32
13200	5.5	7.2	6.5	8.	3.3	4.3	7/32	9/32	17/64	21/64	9/64	11/64
15000	6.	8.4	7.5	9.	3.6	5.	15/64	11/32	19/64	23/64	5/32	13/64
16500	6.8	9.3	8.	10.5	4.1	5.6	17/64	3/8	21/64	27/64	11/64	7/32
20000	8.	11.3	10.	12.5	4.8	6.8	5/16	7/16	13/32	1/2	3/16	17/64
22000	9.	12.5	11.	14.	5.4	7.5	23/64	1/2	7/16	9/16	7/32	19/64
25000	10.	14.	12.5	16.5	6.	8.4	25/64	9/16	1/2	21/32	15/64	21/64
27000	11.	15.5	13.5	18.	6.6	9.3	7/16	5/8	17/32	23/32	17/64	3/8
30000	12.5	17.2	15.5	21.5	7.5	10.3	1/2	11/16	39/64	27/32	19/64	13/32
33000	13.5	19.	17.5	25.	8.1	11.4	35/64	3/4	11/16	1	21/64	29/64
35000	14.5	20.5	19.	28.5	8.7	12.3	37/64	13/16	3/4	1 1/8	11/32	31/64
36000	15.	21.5	20.	30.5	9.	12.9	19/32	27/32	51/64	1 7/32	23/64	33/64

Table 2

Indoor—125—Millimeter Spheres (See Fig. 31)

Voltage	Range in Millimeters						Range in Inches					
	A		B		C		A		B		C	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
30000	13.	17.	15.	19.	7.8	10.2	33/64	11/16	19/32	3/4	5/16	13/32
33000	14.	19.	16.	21.	8.4	11.4	9/16	3/4	41/64	53/64	11/32	29/64
35000	15.	20.5	17.	22.	9.	12.3	19/32	13/16	11/16	7/8	3/8	31/64
40000	17.	22.	19.	24.	10.2	13.2	43/64	7/8	3/4	31/32	13/32	17/32
44000	19.	26.	21.	28.	11.4	15.6	3/4	1 1/32	27/32	1 1/8	29/64	5/8
50000	22.	30.	24.	34.	13.2	18.	7/8	1 3/16	15/16	1 11/32	17/32	23/32
55000	25.	34.	27.	41.	15.	20.4	1	1 11/32	1 1/16	1 5/8	19/32	13/16
60000	27.	37.	29.	47.	16.2	22.2	1 1/16	1 15/32	1 3/16	1 7/8	41/64	7/8
66000	29.	41.	31.5	52.	17.4	24.6	1 5/32	1 5/8	1 1/4	2 1/16	11/16	31/32
70000	31.	44.	35.	56.	18.6	26.4	1 7/32	1 3/4	1 7/16	27/32	3/4	1 1/16
80000	35.	53.	45.	64.	21.	31.8	1 3/8	2 1/8	1 13/16	2 17/32	2 7/32	1 1/4
88000	40.	61.	55.	72.	24.	36.6	1 9/16	2 3/8	2 3/16	2 7/8	31/32	1 7/16

Table 3

Outdoor—3/8-Inch Horns (See Fig. 30)

Voltage	Range in Millimeters						Range in Inches					
	A		B		C		A		B		C	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
5000	2.5	3.5	5.5	6.5	1.5	2.1	7/64	9/64	7/32	1/4	1/16	3/32
6600	3.	4.	6.	7.	1.8	2.4	1/8	5/32	1/4	9/32	5/64	7/64
7200	3.5	5.5	6.5	8.5	2.1	3.3	9/64	7/32	17/64	11/32	3/32	9/64
10000	4.8	7.5	9.	12.	2.9	4.5	3/16	19/64	3/8	15/32	7/64	3/16
11000	5.5	9.	10.	14.	3.3	5.4	7/32	23/64	13/32	9/16	9/64	7/32
13200	6.5	12.5	12.	18.	3.9	7.5	17/64	1/2	1/2	23/32	5/32	19/64
15000	7.5	16.	14.	22.	4.5	9.6	19/64	41/64	9/16	7/8	3/16	3/8

Table 4

IMPULSE GAP SETTINGS

NOTE

For a given voltage the low settings go together and the high settings go together. Gap C should be maintained at about 60 per cent of the settings for Gap A.

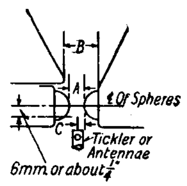


Fig. 32

Outdoor—62.5-Millimeter Spheres (See Fig. 32)

Voltage	Range in Millimeters						Range in Inches					
	A		B		C		A		B		C	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
10000	5.	8.	6.	9.	3.	4.8	13/64	5/16	15/64	11/32	7/64	3/16
11000	5.5	9.	7.	10.	3.3	5.4	7/32	25/64	9/32	25/64	9/64	7/32
13200	6.	10.	7.5	14.	3.6	6.	15/64	13/32	9/64	35/64	9/64	15/64
15000	7.	13.	8.	18.	4.2	7.8	9/32	33/64	5/16	45/64	11/64	19/64
16500	8.	16.	9.	22.	4.8	9.6	5/16	41/64	23/64	7/8	3/16	3/8
18500	9.	19.	10.	27.	5.6	11.4	23/64	3/4	13/32	1 1/16	7/32	7/16
20000	10.	22.	11.	32.	6.	13.4	26/64	7/8	7/16	1 1/4	15/64	33/64
22000	11.	26.	12.	37.	6.6	15.6	7/16	1 1/32	31/64	1 7/16	1/4	39/64
25000	12.	31.	14.	47.	7.2	18.6	15/32	1 7/32	9/16	1 7/8	9/32	47/64
27000	13.	35.	15.	54.	7.8	21.	16/32	1 3/8	19/32	2 1/8	5/16	53/64
30000	14.	41.	19.5	68.	8.4	24.6	9/16	1 5/8	5/8	2 11/16	21/64	31/32
33000	16.	48.	20.	81.	9.6	28.8	41/64	1 29/32	25/32	3 3/16	3/8	1 1/8
35000	17.	52.	21.	90.	10.2	31.2	43/64	2 1/32	53/64	3 9/16	13/32	1 7/32
36000	17.5	54.	22.	96.	10.5	32.4	45/64	2 1/8	7/8	3 3/4	23/64	1 9/32

Table 5

Outdoor—125-Millimeter Spheres (See Fig. 32)

Voltage	Range in Millimeters						Range in Inches					
	A		B		C		A		B		C	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
25000	12.	25.	15.	30.	7.2	15.	15/32	1	19/32	1 3/16	9/32	19/32
30000	14.	33.	18.	43.	8.6	19.8	9/16	1 5/16	23/32	1 23/32	11/32	25/32
33000	16.	39.	19.	52.	9.6	22.4	5/8	1 9/16	3/4	2 1/16	3/8	7/8
35000	17.	43.	20.	57.	10.4	25.8	43/64	1 11/16	51/64	2 1/4	13/32	1
40000	19.5	54.	24.	71.	11.7	32.4	49/64	2 1/8	61/64	2 13/16	29/64	1 9/32
44000	21.5	62.	27.	83.	12.8	37.2	27/32	2 7/16	1 1/16	3 9/32	1/2	1 15/32
50000	25.	75.	37.	101.	15.	45.	1	2 15/16	1 15/32	4	19/32	1 3/4
55000	27.	87.	48.	116.	16.2	52.2	1 1/16	3 7/16	1 29/32	4 19/32	41/64	2 1/16
60000	30.	99.	62.	130	18.	59.4	1 3/16	3 7/8	2 7/16	5 1/8	45/64	2 11/32
66000	33.5	112.	83.	148.	20.1	67.2	1 5/16	4 7/16	3 9/32	5 13/16	51/64	2 21/32
70000	36.	119.	97.	159.	21.6	71.5	1 7/16	4 11/16	3 27/32	6 1/4	27/32	2 13/16
73000	37.5	128.	98.	168.	22.5	7.7	1 1/2	5 1/32	3 7/8	6 5/8	57/64	3 1/32

Table 6

HORN GAP SETTINGS

NOTE

For best results the maximum gap setting should not exceed the diameter of the spheres.

When charging resistance has two gaps in series, divide B equally between the two gaps.

The foregoing settings for the sphere gap, and auxiliary gap, horn gap, are given as approximate, due to the effect local conditions may have on the gap settings. The settings given are the limits of those usually found to give the most satisfactory service, but ultimate purchaser may desire to vary the settings to meet his own particular and peculiar operating conditions.

In any case Gap B should be sufficiently great, that the gap does not arc over when arrester is being charged.

Indoor—3/8-inch Horns—(Main Gap) (See Fig. 33)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
2200	1.	1.3	.8	3/64	1/16	1/32
3300	1.4	1.8	1.2	1/16	5/64	3/64
4400	1.8	2.5	1.6	5/64	7/64	1/16
6600	2.8	3.8	2.4	7/64	5/32	3/32
7200	3.	4.2	2.8	1/8	11/64	3/32
11000	4.3	6.5	3.2	11/64	3/4	1/8
13200	5.6	7.9	4.	7/32	5/16	5/32
16500	7.	10.2	4.8	9/32	13/32	3/16
22000	9.3	14.3	6.4	3/8	9/16	1/4
25000	10.6	16.8	8.5	27/64	21/32	9/32
26500	11.2	18.2	8.7	7/16	23/32	5/8
30000	13.	22.4	11.	17/32	7/8	11/16
33000	14.6	27.	12.7	19/32	1 1/16	1/2
35000	15.7	31.	15.	5/8	1 7/32	19/32
40000	18.5	42.	16.7	3/4	1 21/32	21/32

Table 7

Indoor—5/8-inch Horns—(Main Gap) (See Fig. 33)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
25000	7.5	17.5	8.5	19/64	11/16	9/32
26400	8.5	19.	8.7	11/32	3/4	3/8
30000	11.	23.	11.	7/16	29/32	11/16
33000	13.	28.	12.7	1/2	1 1/8	1/2
35000	14.	32.	15.	9/16	1 1/4	19/32
40000	18.	44.	16.7	23/32	1 9/16	21/32
44000	22.	57.	19.	7/8	2 1/4	3/4
50000	28.	70.	23.	1 1/8	2 3/4	29/32
55000	37.	102.	26.	1 15/32	4	1 1/32
60000	45.	124.	29.	1 3/4	4 7/8	1 1/8
66000	58.	152.	31.5	2 9/32	6	1 1/4
70000	66.	170.	34.	2 5/8	6 3/4	1 11/32
88000	108.	250.	43.	4 1/4	9 7/8	1 3/4
100000	160.	305.	51.	6 1/4	12	2

Table 8

HORN GAP SETTINGS

NOTE

For best results the maximum gap setting should not exceed the diameter of the spheres.

When charging resistance has two gaps in series, divide B equally between the two gaps.

The foregoing settings for the sphere gap, and auxiliary gap, horn gap, are given as approximate, due to the effect local conditions may have on the gap settings. The settings given are the limits of those usually found to give the most satisfactory service, but ultimate purchaser may desire to vary the settings to meet his own particular and peculiar operating conditions.

In any case Gap B should be sufficiently great, that the gap does not arc over when arrester is being charged.

Indoor—3/4-inch Horns—(Main Gap) (See Fig. 33)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
60000	30.	67.	29.	1 3/16	2 5/8	1 1/8
66000	35.	85.	32.	1 3/8	2 3/8	1 1/4
70000	40.	96.	34.	1 9/16	3 3/4	1 11/32
88000	66.	147.	42.	2 5/8	5 3/4	1 21/32
95000	78.	170.	47.	3 1/16	6 11/16	1 7/8
100000	87.	187.	50.	3 7/16	7 7/8	2
105000	96.	204.	53.	3 13/16	8 1/16	2 3/32
110000	105.	220.	55.	4 1/8	8 11/16	2 3/16
115000	115.	238.	60.	4 1/2	9 3/8	2 3/8
120000	124.	256.	64.	4 7/8	10 1/16	2 9/16
125000	135.	276.	67.	5 5/16	10 7/8	2 11/16
130000	144.	297.	71.	5 11/16	11 11/16	2 13/16
135000	155.	322.	75.	6 1/8	12 3/4	2 15/16
140000	166.	350.	76.	6 9/16	13 3/4	3 1/32

Table 9

Outdoor—3/8-inch Horns—(Main Gap) (See Fig. 33)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
5000	7.	9.	1.8	9/32	11/32	3/32
6600	8.	11.	2.4	5/16	7/16	3/32
7200	9.	13.	2.8	11/32	1/2	3/32
11000	13.	19.	3.2	1/2	3/4	1/8
13200	16.	24.	4.0	5/8	15/16	5/32
16500	20.	30.	4.8	13/16	1 3/16	3/16
22000	27.	42.	6.4	1 1/16	1 5/8	1/4
25000	31.	49.	8.5	1 1/4	1 13/16	9/32
26500	33.	52.	8.7	1 5/16	2 1/16	5/8
30000	39.	62.	11.	1 9/16	2 7/16	7/16
33000	44.	76.	12.7	1 3/4	3	1/2
35000	48.	79.	15.	1 7/8	3 1/8	19/32
40000	58.	103.	16.7	2 1/4	4 1/16	21/32

Table 10

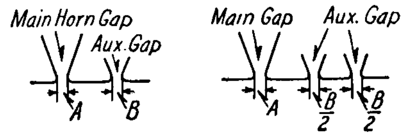


Fig. 33

Outdoor—5/8-inch Horns—(Main Gap) (See Fig. 33)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
25000	32.	51.	8.5	1 1/4	2	9/32
26400	34.	57.	8.7	1 11/32	2 1/8	3/8
30000	40.	63.	11.	1 9/16	2 1/2	11/16
33000	45.	77.	12.7	1 3/4	3 1/32	1/2
35000	49.	80.	15.	1 15/16	3 3/16	19/32
40000	59.	105.	16.7	2 5/16	4 1/8	21/32
44000	64.	124.	19.2	2 1/2	4 7/8	3/4
50000	82.	152.	23.	3 1/4	5 7/8	29/32
55000	95.	172.	26.	3 3/4	6 3/4	1 1/32
60000	109.	200.	29.	4 5/16	7 7/8	1 1/8
66000	126.	210.	31.5	4 15/16	8 1/4	1 1/4
70000	137.	245.	34.	5 3/8	9 5/8	1 11/32
88000	192.	316.	43.	7 9/16	12 9/16	1 3/4
95000	210.	348.	45.	8 1/4	13 3/16	1 7/8
100000	228.	368.	51.	9	14 1/2	2

Table 11

Outdoor—3/4-inch Horns—(Main Gap) (See Fig. 33)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
60000	110.	200.	29.	4 5/16	7 7/8	1 1/16
66000	126.	210.	32.	5	8 1/4	1 1/4
70000	137.	245.	34.	5 3/8	9 5/8	1 11/32
88000	192.	316.	42.	7 9/16	12 7/16	1 21/32
95000	210.	348.	47.	8 1/4	12 3/4	1 7/8
100000	228.	368.	50.	9	14 1/2	2
105000	240.	384.	55.	9 7/16	15 1/8	2 3/32
110000	255.	404.	60.	10	15 7/8	2 7/16
115000	270.	424.	64.	10 5/8	16 11/16	2 3/8
120000	286.	445.	67.	11 1/4	17 1/2	2 9/16
125000	296.	465.	69.	11 5/8	18 5/16	2 11/16
130000	308.	484.	71.	12 3/16	19 1/16	2 13/16
135000	328.	505.	75.	12 15/16	19 7/8	2 15/16
140000	340.	544.	76.	13 5/16	21 7/16	3 1/32

Table 12

SPHERE GAP SETTINGS

NOTE

For best results the maximum gap setting should not exceed the diameter of the spheres.

When charging resistance has two gaps in series, divide B equally between the two gaps.

The foregoing settings for the sphere gap, and auxiliary gap, horn gap, are given as approximate, due to the effect local conditions may have on the gap settings. The settings given are the limits of those usually found to give the most satisfactory service, but ultimate purchaser may desire to vary the settings to meet his own particular and peculiar operating conditions.

In any case Gap B should be sufficiently great, that the gap does not arc over when arrester is being charged.

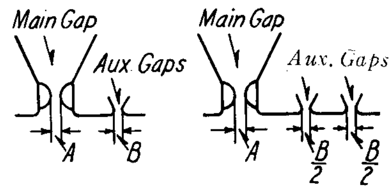


Fig. 34

Indoor—62.5-Millimeter Spheres (See Fig. 34)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
6600	2.5	3.3	2.4	3/32	9/64	3/32
7200	2.8	3.5	2.8	7/64	9/64	5/32
8500	3.0	4.0	3.0	1/8	5/32	1/8
11000	4.4	5.3	3.2	5/32	7/32	1/8
13200	4.8	6.3	4.0	13/64	1/4	5/32
16500	6.	8.	4.8	15/64	5/16	3/16
22000	9.	12.	6.4	23/64	31/64	1/4
25000	10.2	13.5	8.5	13/32	17/32	9/32
26400	11.0	14.5	8.7	7/16	37/64	5/8
30000	12.5	16.0	11.0	1/2	41/64	11/16
33000	13.8	18.0	12.7	53/64	23/32	1/2
35000	14.8	19.0	15.	19/32	3/4	19/32
44000	19.	26.	19.	3/4	1 1/32	3/4
50000	21.8	32.5	23.	55/64	1 9/32	29/32
55000	24.8	40.	26.	63/64	1 37/64	1 1/32
60000	27.5	47.	29.	1 3/32	1 55/64	1 1/8
65000	32.3	58.	31.5	1 9/32	2 9/32	1 1/4
70000	35.5	64.	34.	1 13/32	2 17/32	1 11/32

Table 13

Indoor—125-Millimeter Spheres (See Fig. 34)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
26400	11.	15.	8.7	7/16	19/32	3/8
33000	14.	19.	12.7	35/64	3/4	1/2
35000	15.	20.	15.	19/32	51/64	19/32
44000	19.	29.5	19.2	3/4	1 11/64	3/4
50000	21.	34.	23.	53/64	1 11/32	25/32
55000	24.	38.	26.	61/64	1 1/2	1 1/32
60000	26.5	41.5	29.	1 1/64	1 41/64	1 1/8
66000	29.5	46.	31.5	1 11/64	1 13/16	1 1/4
70000	31.5	49.5	34.	1 1/4	1 61/64	1 11/32
80000	36.5	61.	39.	1 7/16	2 25/64	1 9/16
88000	41.	70.	43.	1 5/8	2 49/64	1 3/4
95000	45.	79.	45.	1 23/32	3 1/8	1 7/8
100000	48.	86.	51.	1 57/64	3 25/64	2
105000	50.5	94.	52.	2	3 45/64	2 1/16
110000	54.	101.	55.	2 9/64	3 31/32	2 5/16
115000	57.	108.	60.	2 1/4	4 1/4	2 3/8
120000	61.	115.	64.	2 13/32	4 17/32	2 9/16
125000	65.	124.	67.	2 9/16	4 57/64	2 11/16
130000	69.	133.	71.	2 23/32	5 15/16	2 13/16

Table 14

SPHERE GAP SETTINGS

NOTE

For best results the maximum gap setting should not exceed the diameter of the spheres.

When charging resistance has two gaps in series, divide B equally between the two gaps.

The foregoing settings for the sphere gap, and auxiliary gap, horn gap, are given as approximate, due to the effect local conditions may have on the gap settings. The settings given are the limits of those usually found to give the most satisfactory service, but ultimate purchaser may desire to vary the settings to meet his own particular and peculiar operating conditions.

In any case Gap B should be sufficiently great, that the gap does not arc over when arrester is being charged.

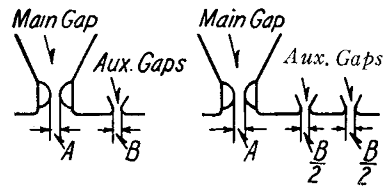


Fig. 35

Outdoor—62.5-Millimeter Spheres—(Main Gap) (See Fig. 35)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
11000	5.5	8.5	3.2	7/32	11/32	1/8
13200	6.	11.	4.	1/4	7/16	5/32
16500	8.6	16.	4.8	11/32	5/8	3/16
22000	10.2	26.	6.4	13/32	1 1/32	1/4
25000	12.	32.	8.5	15/32	1 1/4	9/32
26400	12.6	35.	8.7	1/2	1 3/8	5/8
30000	14.4	41.5	11.	9/16	1 5/8	7/16
33000	16.	47.	12.7	5/8	1 7/8	1/2
35000	17.	52.	15.	11/16	2 1/16	19/32
40000	19.4	62.	16.7	3/4	2 7/16	21/32
44000	21.4	68.	19.2	27/32	2 11/16	3/4
50000	24.4	80.	23.	31/32	3 1/8	29/32
55000	26.8	89.	26.	1 1/32	3 1/2	1 1/32
60000	29.2	99.	29.	1 5/32	3 7/8	1 1/8
63500	31.	10.5	30.5	1 7/32	4 1/8	1 3/16

TABLE 15

Outdoor—125-Millimeter Spheres—(Main Gap) (See Fig. 35)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap A
	Low	High		Low	High	
22000	12.	25.	8.5	15/32	1	9/32
26400	13.	28.	8.7	1/2	1 3/32	3/8
30000	14.	33.	11.	9/16	1 5/16	11/16
33000	16.	39.	12.7	5/8	1 9/16	1/2
35000	17.	43.	15.	43/64	1 11/16	19/32
40000	19.5	54.	16.7	49/64	2 1/8	21/32
44000	21.5	62.	19.2	27/32	2 7/16	3/4
50000	25.	75.	23.	1	2 15/16	29/32
55000	27.	87.	26.	1 1/16	3 7/16	1 1/32
60000	30.	99.	29.	1 3/16	3 7/8	1 1/8
66000	33.5	112.	31.5	1 5/16	4 7/16	1 1/4
70000	36.	119.	34.	1 7/16	4 11/16	1 11/32
88000	43.	160.	43.	1 11/16	6 5/16	1 3/4
95000	50.	175.	45.	2	6 7/8	1 7/8
100000	55.	186.	51.	2 3/16	7 5/16	2

TABLE 16

Outdoor—175-Millimeter Spheres—(Main Gap) (See Fig. 35)

Voltage	Range in Millimeters			Range in Inches		
	Gap A		Gap B	Gap A		Gap B
	Low	High		Low	High	
60000	55.	74.	29.	2 5/32	2 15/16	1 1/8
66000	61.	85.	31.5	2 3/8	3 3/8	1 1/4
70000	64.	89.	34.	2 1/2	3 9/16	1 11/32
80000	78.	104.	39.	3 1/16	4 1/8	1 16/32
88000	84.	111.	43.	3 5/16	4 3/8	1 21/32
95000	89.	122.	45.	3 9/16	4 13/16	1 7/8
100000	96.	131.	51.	3 13/16	5 3/16	2
105000	100.	140.	53.	3 15/16	5 1/2	2 3/32
110000	105.	150.	55.	4 1/8	5 7/8	2 3/16
115000	111.	167.	60.	4 3/8	6 9/16	2 3/8
120000	117.	175.	64.	4 5/8	6 7/8	2 9/16
125000	122.	189.	67.	4 13/16	7 1/2	2 11/16
130000	127.	200.	71.	5	7 7/8	2 13/16
135000	133.	218.	75.	5 7/32	8 9/16	2 15/16
140000	140.	239.	76.	5 17/32	9 7/16	3 1/32
145000	150.	278.	82.	5 15/16	11	3 1/4
150000	167.	294.	87.	6 9/16	11 5/8	3 7/16
155000	170.	326.	91.	6 11/16	12 13/16	3 9/16
160000	177.	350.	96.	7	13 3/4	3 13/16
165000	188.	378.	100.	7 3/8	14 7/8	3 15/16

TABLE 17

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

WESTINGHOUSE SALES OFFICES

ABILENE, KAN., 300 N. Cedar St.
ABILENE, TEX., 109 N. 2nd. St.
ALBANY, N. Y., Journal Bldg.
*ATLANTA, GA., Westinghouse Elec. Bldg., 426 Marietta St.
BAKERSFIELD, CAL., 2224 San Emedio St.
*BALTIMORE, MD., West. Elec. Bldg., 121 E. Baltimore St.
BIRMINGHAM, ALA., 1407 Age-Herald Bldg., 2030-2nd Ave.
BLUEFIELD, W. VA., Peery Bldg., Bland & Federal Sts.
*BOSTON, MASS., Rice Bldg., 10 High St.
BRIDGEPORT, CONN., Bruce Ave. & Seymour Streets
*BUFFALO, N. Y., Ellicott Square Bldg., Ellicott Square
BURLINGTON, IOWA, 315 North Third St.
*BUTTE, MONT., Montana Elec. Co. Bldg., 52 East Broadway.
CANTON, OHIO, (Box 292-Mail and Telegrams)
CASPER, WYO., 201 Cottman Bldg., 124 W. 2nd Ave.
CEDAR RAPIDS, IOWA, 1616 Fifth Ave., (Mail P. O. Box 1067)
CHARLES ON, W. VA., Capitol & Virginia Sts.
*CHARLOTTE, N. C., 210 E. 6th St., Westinghouse Elec. Bldg.
CHATTANOOGA, TENN., Market & Sixth Sts.
*CHICAGO, ILL., Conway Bldg., 111 W. Washington Street.
*CINCINNATI, OHIO, West. Elec. Bldg., Third and Elm Sts.
*CLEVELAND, OHIO, Station "B" Westinghouse Electric Bldg., 2209 Ashland Rd., S. E.
*COLUMBUS, O., Interurban Terminal Bldg., Third and Rich Sts.
*DALLAS, TEX., Magnolia Bldg., Akard and Commerce Streets.
DAVENPORT, IA., Central Office Building.
DAYTON, O., Realty Bldg., 132 N. Main Street.
*DENVER, COLO., Gas & Electric Bldg., 910 Fifteenth St.
DES MOINES, IOWA, Equitable Bldg., W. 6th & Locust Streets.
*DETROIT, MICH., Westinghouse Elec. Bldg., 1535 Sixth St.
DULUTH, MINN., Bradley Bldg., Lake Ave. & Superior St.
ELMIRA, N. Y., Hulett Bldg., 338-342 E. Water St.
*EL PASO, TEX., Mills Bldg., Oregon and Mills St.
ERIE, PA., 1015 State Street.
EVANSVILLE, IND., P. O. Box 457
FAIRMONT, W. VA., 613 Maryland Ave.
FORT WAYNE, IND., 1010 Packard Ave.
FRESNO, CAL., Griffith-McKenzie Bldg., J and Mariposa Sts.
GRAND RAPIDS, MICH., 422 Kelsey Bldg., Pearl & Ottawa Sts.
HAMMOND, IND., 1238 Jackson St.
HARTFORD, CONN., 36 Pearl St., U. S. Security Trust Bldg.
*HOUSTON, TEX., Main St. & Congress Ave.
*HUNTINGTON, W. VA., West. Elec. Bldg., Cor. 2nd Ave. & 9th St.
*INDIANAPOLIS, IND., West. Elec. Bldg., 820 N. Senate Ave.
ISHPEMING, MICH., 507 N. 5th St.
JACKSON, MICH., 704 Peoples National Bank Bldg.
JACKSON, MISS., P. O. Box 141
JACKSONVILLE, FLA., Union Term. Bldg., E. Union & Ionia Sts.
JOHNSTOWN, PA., 47 Messenger St.
JOPLIN, MO., P. O. Box 653.
*KANSAS CITY, MO., 2124 Wyandotte St., West. Elec. Bldg.
KNOXVILLE, TENN., 413 Bankers Trust Bldg.
LITTLE ROCK, ARK., 2311 State Street.
LOUISVILLE, KY., 5th Floor, Citizens Bldg., 6th and 'efferson St.
*LOS ANGELES, CAL., West. Elec. Bldg., 420 S. San Pedro St.
MADISON, WIS., P. O. Box 222.
MARSHALL, TEX., 507 N. Boliver St.
MEDFORD ORE., W. Main St.
MEMPHIS, TENN., Exchange Bldg., 130 Madison Ave.
MIAMI, FLA., 406 N. E. 2nd Ave., 202 Coolidge Bldg.
MIDDLESBORO, KY., (P. O. Box 518).
MILWAUKEE, WIS., First National Bank Bldg., 425 E. Water St.
*MINNEAPOLIS, MINN., Northwestern Terminal, 2303 Kennedy St. N. E.
MOBILE, ALA., 113 Macy Ave.
NASHVILLE, TENN., 910 Broadway
NEWARK, N. J., 38-40 Clinton St.
NEW HAVEN, CONN., Liberty Bldg., 152 Temple St.
*NEW ORLEANS, LA., Maison Blanche Bldg., 921 Canal St.
*NEW YORK, N. Y., West. Elec. Bldg., 150 Broadway.
NIAGARA FALLS, N. Y., Gluck Bldg., 205 Falls Street.
NORFOLK, VA., Nat. Bank of Commerce Bldg., 300 Main St.
OKLAHOMA CITY, OKLA., Main & Broadway St.
OMAHA, NEB., 1102 Woodmen of World Bldg., 1319 Farnam St.
PEORIA, ILL., 417 Peoria Life Bldg., 214 Cooper St.
*PHILADELPHIA, PA., West. Elec. Bldg., 30th & Walnut Sts.
*PHOENIX, ARIZ, 412 Luhrs Bldg., 11 West Jefferson St.
PINE BLUFF, ARK., 1603 W.-17th Ave., P. O. 753.
*PITTSBURGH, PA., Commerce Bldg., 7th & Smithfield Sts.
PORTLAND, MAINE, 61 Woodford St.
PORTLAND, ORE., 901-2-3 Porter Bldg., Sixth and Oak Sts.
POUGHKEEPSIE, N. Y., Bardavon Bldg., 35 Market St.
PROVIDENCE, R. I. 393 Harris Ave.
PUEBLO, COL., 112 Central Block Bldg., 124 N. Main St.
RALEIGH, N. C., 803 N. Person St.
RICHMOND, VA., Va. Rwy. and Pr. Bldg., 7th & Franklin Sts.
ROCHESTER, N. Y., Commerce Bldg., 119 E. Main Street.
ROCKFORD, ILL., 414 Stewart Bldg., 1107 North Ave.
RUTLAND, VT., 9 Kingsley Court
SACO, MAINE, R. F. D. No. 2.
*SALT LAKE CITY, UTAH, Interurban Terminal Bldg.
SAN ANTONIO, TEXAS, 807 Frost National Bank Bldg.
SAN DIEGO, CAL., 512 Electric Bldg.
*SAN FRANCISCO, CAL., First Nat. Bank Bldg., 1 Montgomery St.
*SEATTLE, WASH., West. Elec. Bldg., 3451 E. Marginal Way.
SHREVEPORT, LA., 402 City Bank Bldg.
SIOUX CITY, IOWA, 508 Davidson Bldg., P. O. Box 294
SOUTH BEND, IND., 803 Sherland Bldg.
SPOKANE, WASH., Riverside & Stevens Sts.
SPRINGFIELD, ILL., Public Service Bldg., 130 S. Sixth St.
SPRINGFIELD, MASS., 395 Liberty St.
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SYRACUSE, N. Y., University Bldg., S. Warren & E. Wash. Sts.
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*TAMPA, FLA., 417 Ellamae Ave.
TERRE HAUTE, IND., 302 Terre Haute Trust Bldg.
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TULSA, OKLAHOMA, Mid. Continent Bldg., 5th & Boston Ave.
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WATERTOWN, N. Y., 254 Woolworth Bldg., Public Square.
WICHITA, KAN., P. O. Box 1226
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The HAWAIIAN ELECTRIC Co., Ltd., Honolulu, T. H.—Agent

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(KFKX—The Pioneer Radio Repeating Station)

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BINGHAMTON, N. Y., H. C. Roberts Electric Supply Co.
BIRMINGHAM, ALA., Moore-HandleyH'dw'e Co.
BLUEFIELD, WEST VA., Superior Supply Co.
BOSTON, MASS., Wetmore-Savage Electric Supply Co.
BUFFALO, N. Y., McCarthy Bros. & Ford.
BUTTE, MONTANA, The Montana Electric Co.
CHICAGO, ILL., Illinois Electric Co.
CHARLOTTE, N. C., Carolina States Electric Co.
CINCINNATI, O., The Johnson Electric Sup. Co.
CLEVELAND, OHIO, The Erner Electric Co.
COLUMBIA, S.C., Mann Electric Supply Co.,Inc.
DALLAS, TEXAS, Electric Appliance Co.
DENVER, COLO., The Mine & Smelter Sup. Co.
DETROIT, MICH., Commercial Electric Sup. Co.
DULUTH, MINN., Duluth Electrical Supplies Co.
EL PASO, TEXAS, The Mine & Smelter Sup. Co.
ERIE, PA., Star Electrical Co.
EVANSVILLE, IND., The Varney Elect'l Sup. Co.
HOUSTON, TEXAS, Tel-Electro Co.
HUNTINGTON, W. VA., Banks-Miller Supply Co.
INDIANAPOLIS, IND., The Varney Electrical Supply Co.
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KANSAS CITY, MO., Columbian Electrical Co.
LOS ANGELES, CAL., Illinois Electric Co.
LOUISVILLE, KY., Tafel Electric Co.
MASON CITY, IOWA, Julius Andrae & Sons Co.
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CANADIAN COMPANY

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