THE UNIVERSITY OF MISSOURI BULLETIN

Number 7
ENGINEERING EXPERIMENT STATION
Volume 3 Number 1

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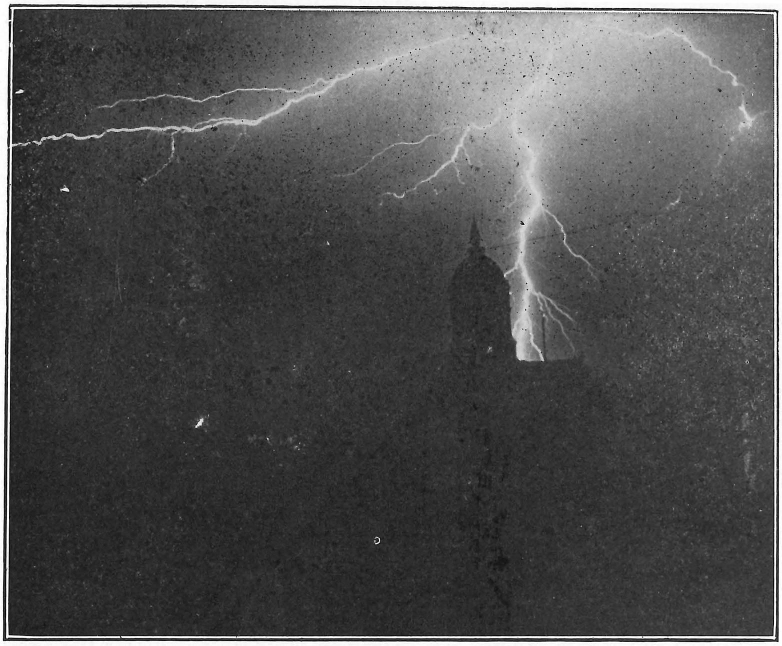


INTRODUCTION.

There is a widespread popular belief that lightning-rods are of little or no value. Years may pass by without a single case of lightning stroke in a whole village or town of unrodded houses. On the other hand, one reads occasionally of a rodded building being struck and burned.

If rodded buildings are sometimes struck while thousands with no rods escape, what reason is there for supposing that rods give any protection?

It is clear that the rods do not give complete protection, but it may very well be that they reduce the danger of lightning stroke, giving a partial protection. Whether this is true or not can hardly be judged from the few cases that come to the attention of the individual. It must be tested by extended observations covering a great many buildings and a considerable period of time.

The reports of the Farmers' Mutual Fire Insurance Associations of Iowa and Missouri throw some light on this question. Delegates from the different counties meet each year in convention, and the question is asked:

"Did you have any losses from lightning on rodded buildings?"

The following table shows the experience in Missouri. The number of associations reporting no damage to rodded buildings gives an idea of the extent of the territory covered, while the heavy losses to other property caused by lightning, show that the lightning had by no means been idle, and the rodded buildings must have had plenty of chance to be struck. Nevertheless, during the three years there were only eleven cases of damage to rodded buildings in the State of Missouri, and in most of these cases the damage was slight:

	Number of Cases or Damage to Roded Buildings.	Number of County Associations Reporting No Damage to Rodded Buildings.	TABLE NO. 1 Total Amount Paid Out for Losses from Lightning.
1909	1	Not stated in report	$29,755.23
1910	4	63	97,361.39
1911	6 none serious	62	91,678.95

The experience of the Iowa Farmers' Mutual Fire Insurance Association has been very much the same, only about one county in ten reported any cases of damage to rodded buildings, while nine counties out of ten had had some of their unrodded buildings struck and injured each year.

REPORTS OF THE IOWA FARMERS' MUTUAL FIRE INSURANCE ASSOCIATIONS.

Year.	Number of Associations Reporting Damage to Rodded Bldgs.	Number of Associations Reporting No Damage to Rodded Bldgs.	Number of Associations reporting Damage to Unrodded Bldgs.	Number of Associations reporting No Damage to Unrodded Bldgs.
1908	6	43	44	7
1909	3	36	42	3

In most of the cases of damage to buildings with rods the cause was found to be defective or incomplete rodding.

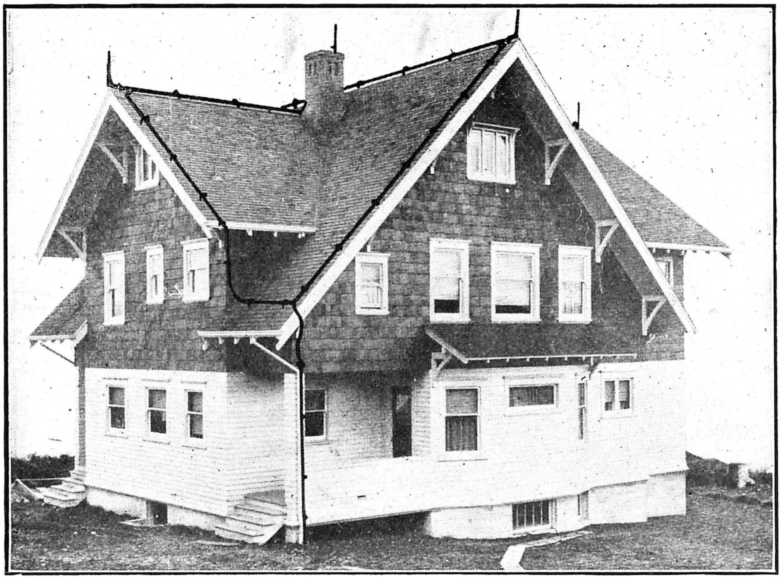
Still more instructive are the reports of amounts paid out by the Iowa Farmers' Mutual Fire Insurance Associations for damage by lightning.

FARMERS' MUTUAL FIRE INSURANCE ASSOCIATIONS OF IOWA.

Year.	Losses on Buildings and Contents Resulting from Lightning.	
	Buildings Rodded.	Buildings Not Rodded.
1908	$125.60	$46,010.22
1909	953.00	35,076.65
Total for 1908 and 1909.	$1,078.60	$81,076.87

These figures show that during these two years the unrodded buildings suffered nearly eighty times as much damage from lightning as those with rods. The total losses for four years, 1908 to 1911, show the unrodded buildings as suffering sixty times more heavily.

In order to arrive at a fair estimate of the protective value of the



rods, it would be necessary to compare the damage that occurred to a given number of rodded buildings with the damage to an equal number of unrodded buildings during the same period of time. There are probably about four unrodded to one rodded building in the State of Iowa—we are speaking of the larger farm houses and barns. Therefore, we must divide the $180,000 total loss on unrodded buildings by four, which will give $4,500 as the damage suffered by unrodded buildings equal in number to those with rods. To illustrate, suppose that the insured farm buildings of the State numbered 100,000, of which 80,000 had no rods. The loss on the 20,000 rodded buildings amounted to $3,000, and the loss on the 80,000 that were without rods was $180,000. The loss on 20,000 of the unrodded buildings would have been one-fourth of $180,000, or $45,000, which is fifteen times as great as the damage suffered by 20,000 similar buildings that were provided with rods.

The conclusion from these figures, then, would be that rodding reduced the damage from lightning to something like one-fifteenth part of what it was without the rods; and this, it should be remembered, was the result, not of the best possible system of rodding, but of good rods and poor ones taken together.

The lightning rod, however, has not proved as useful in this country as it might, on account of ignorance of its true value, and on account of the fact that rods have frequently cost a good deal more than they needed to.

It is unwise to rod some buildings, and it is foolish to leave some others unrodded. In some cases the cheapest system possible should be used; in others a better and more expensive kind of rodding is justified.

It is the purpose of this bulletin to set forth in an impartial way and as simply and clearly as possible, such facts as will assist the reader first, to decide wisely whether or not to rod his building; secondly, to enable him to understand how lightning rods operate and how they should be constructed, and to compare the merits of different rods and rodding systems; thirdly, to give such directions that any one who wishes can buy the materials and place a satisfactory system of lightning conductors on his own buildings; and lastly, to offer some other suggestions in regard to safety from lightning, which may be of value.

HISTORY AND DEVELOPMENT OF THE USE OF LIGHTNING RODS.

It was Benjamin Franklin to whom the idea first occurred that lightning might be the same thing, only on a gigantic scale, as the electric sparks a few inches long that men had produced in laboratories. Although the two seemed so different, Franklin noticed that they had some remarkable points of similarity. Artificial electric sparks are like lightning in the peculiar crooked courses they take, their suddenness, the color of the light produced, and the odor that follows. Both produce noise, can kill animals, set fire to inflammable materials, rend bodies which they pass through, and are carried easily by metals, but sometimes melt the metal if it is not large enough.

Franklin's Experiment.—With these facts in mind Franklin devised a scheme to draw a small quantity of the electrical energy (if it should really prove to be electrical) from a storm cloud. On July 4, 1752, he succeeded in doing this with the help of a kite; and the sparks he drew from a key suspended at the lower end of the kite-string were exactly like those that he had produced in his laboratory. Thus he demonstrated to his own satisfaction, and to the satisfaction of the whole scientific world, that lightning and electricity are identical.

Invention of the Lightning Rod.—The first use Franklin made of his discovery was to devise a way of protecting buildings from lightning. Having been a student of electricity for a number of years, he knew at once what the method of protection should be. He announced his discovery to the public in the pamphlet called "Poor Richard's Almanac," of which he was publisher, in the following words:

"It has pleased God in his goodness to mankind, at length to discover to them the means of securing their habitations and other buildings from mischief by thunder and lightning. The method is this: Provide a small iron rod, which may be made of the iron rod used by nailors, but of such length that one end being three or four feet in the moist ground, the other may be six or eight feet above the highest part of the building. To the upper end of the rod fasten about a foot of brass wire, the size of a common knitting needle, sharpened to a fine point; the rod may be secured on the house by a few small staples. If the house or barn be long there may be a rod and point at each end, and a middling wire along the ridge from one to the other. A house thus furnished will not be damaged by lightning, it being attracted by the points, and passing through the metal into the ground, without hurting anything. Vessels also having a sharp pointed rod fixed to the top of their masts, with a wire from the foot of the rod reaching down around one of the shrouds to the water, will not be hurt by lightning."

Growth in the Use of Lightning Rods.—Franklin and his friends immediately set to work to induce their fellow countrymen to place lightning rods on their houses. They set the example by protecting their own houses with rods. It was not a great while before some of these were put to the test. Mr. West, a Philadelphia merchant, was one of the first to provide his house with the kind of rod that Franklin recommended. A thunder storm occurred soon after it was finished and lightning struck the point of the rod. The stroke was witnessed by a number of people, who reported that they had also seen a flash near the foot of the rod. The house was not injured. On hearing of the flash at the base of the rod, Franklin concluded that the lightning must have left the rod because its connection with the earth was poor. By digging down a few feet he found that he was right, for the rod only reached down five feet and the ground around it was perfectly dry. He also examined the brass point and found that it had melted and run down much like the grease on a candle. Afterwards the brass or copper points were made of heavier wire and there was little further trouble of this kind.

A few cases such as this, where heavy strokes of lightning left houses uninjured, were enough to convince people that these rods afforded real protection. Nevertheless, there was a great deal of opposition to them at first and their use spread rather slowly.

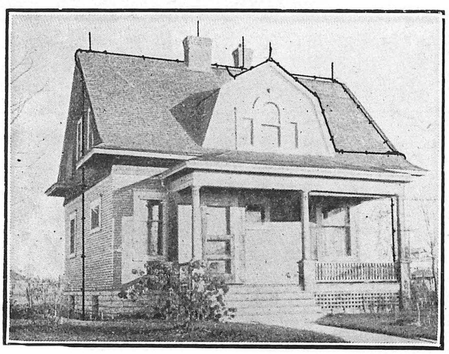
The Situation in America.—About a hundred years later, when the value of rods was conceded by every one, an unfortunate state of affairs arose in this country. Hosts of unscrupulous men, pretending to be experts, traveled through the land selling worthless rods at ten times what the material in them cost, imposing on ignorant people, and leaving in their trail rods that were so carelessly erected that they were as likely to be a source of danger as protection. The ability of a simple metal conductor to ward off danger of lightning seemed so wonderful and mysterious that it was easy to persuade people that some peculiar form of gilded ornamental tip, or a special shaped bar was the real secret of success of the particular rod the agent happened to be selling.

In a book on "Lightning Conductors" by Richard Anderson, published in London in 1885, the situation in this country was described about as follows:

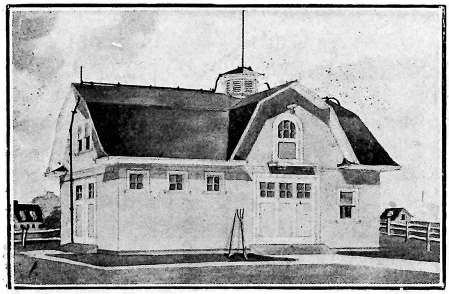
"America stands pre-eminent above all other countries in the numerous schemes that have been devised for the protection of buildings from the effects of lightning, and probably no other nation has been so systematically victimized and swindled in the matter. The tramping 'lightning-rod men' of the United States have been notorious for extortion and ignorance; they use all kinds of fantastic and peculiar shaped terminal rods and conductors, the main object apparently being to make as great a show with as little material as possible. Their work is almost entirely confined to the upper portion of the conductor, to the absolute neglect of the most important part—the earth terminal. The majority of the lightning conductors in America are consequently untrustworthy; very often they are practically insulated by the dry soil from the ground water, to which the lightning must find its way. They are therefore in such cases more a source of danger than a protection. Unhappily these traveling impostors are by no means extinct, although increased knowledge is gradually driving them out of the field."

It was natural that after such experiences as these, people should distrust all salesmen of lightning rods, and doubt whether any rods were of value. Lightning rods came to be regarded very much as "gold bricks," as a sign of ignorance on the part of the buyer. The man who bought a rod was ridiculed and the rod itself considered as a joke.

Fortunately a more healthy state of affairs in this respect is gradually coming about. In cities and towns there does not usually seem to be much need of lightning rods, but in the country there is still considerable destruction by lightning, and the rod is recognized as its true worth. Greater intelligence on the part of the farmer and reasonable caution enable him to buy what he needs in the way of a lightning-rod without being swindled. Besides the ignorant "frauds" who are still found occasionally, there are respectable companies making and selling lightning-rods, who know their business and do not make unwarranted claims for their rods. The best way to distinguish between the agent who represents a respectable firm and the "quack" is to learn as much as possible about lightning and lightning



protection by reading, and to compare the statements of a number of different companies before buying. One fairly good test is to find out how much pains the company takes in getting a good ground connection. This part is very important, and is hidden under ground. After the rod is in place no one knows whether the ground connection is good or bad. The representative of the firm which really seeks to protect the buildings of its customers will take great care to secure the best possible ground connection.



ELECTRICITY AND LIGHTNING.

Fundamental Facts About Electricity.—Electricity is a form of energy that shows itself in two different states—stored electricity and electricity in action or flowing.

Charges.—Electrical energy can be locked up or stored, and is then spoken of as an "Electric Charge."

Insulators.—In order that it may stay imprisoned it must be surrounded by some material through which it can not pass. Such materials are called "insulators" or "non-conductors," and a few of the most common of these are: air, glass, rubber, oil, marble and slate. Many other substances, such as paper, wood, sand, clay and stone are fairly good insulators, provided they are perfectly dry.

The following table gives some common materials arranged in order of their conducting power:

Good Conductors.	Poor Conductors.	Poor Insulators	Good Insulators
Copper	Solution of salt or lye	Porous stones	Dry gas or air
Aluminum	Dirty water	Dry earth	Varnish
Iron	Clean water & ice	Dry wood, leather or paper	Glass
Lead	Substances containing water, such as plants, animals and moist earth.	Oil and grease	Rubber
Other metals		Silk	Sulphur
Graphite		Paint	Mica
Charcoal and Coke		Dry sand	

Conductors.—There are other materials, however, through which the electricity can pass with more or less ease. Such materials are called "conductors."

By "good conductor" we mean one that offers very little obstruction or "resistance" to the passage of electricity. The other materials named as conductors show resistances hundreds or thousands of times greater than that of metals, but they may still be classed as conductors. Dirty or salty water is a much better conductor than pure water.

The word "conductor" is also used to designate any piece of conducting material, and it is frequently used here in the special sense of lightning rod.

Charges Reside in Conductors.—When charges of electricity are found they are nearly always in some body of conducting material that is surrounded by an insulator, such as a metal plate in air. In nature the stored electricity is in the cloud which consists of minute drops of water, and it is imprisoned by the surrounding air, which is an insulator.

Two Kinds of Electric Charges.—There are two kinds of charges, which are respectively called "positive" and "negative."* Taken by

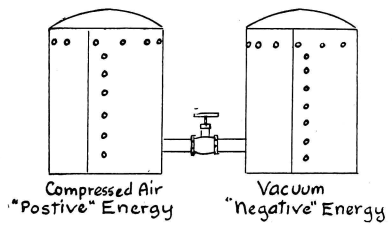


Fig. 1. When the valve is opened the two kinds of energy neutralize.

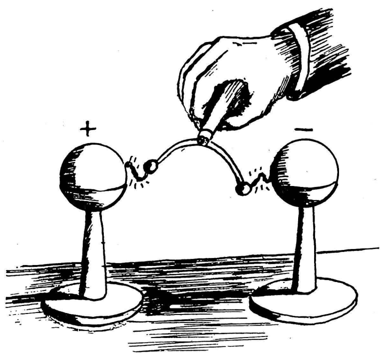


Fig. 2. Discharging a pair of charged conductors.

*We might compare a positively and a negatively charged conductor to two tanks, one with air under pressure and the other with the air pumped out. Both tanks represent stored energy. We could attach a steam engine to the high pressure tank in place of a boiler and the engine would run. We could also run the engine for a few strokes by means of the vacuum tank by connecting the exhaust pipe of the engine to the tank and leaving the steam pipe open to the atmosphere. The air from outside would be drawn through the engine by suction and make it run. Hence we can say that the vacuum is just as truly stored energy as is the compressed air. Both tend to break the tank if it is weak, and both can be made to run the engine.

But if the two tanks were connected together by a pipe, the two kinds of energy would neutralize each other, just as the two charges of electricity neutralize.

themselves they are very much alike, and it is not easy to tell which is which; but they behave differently towards each other. A piece of material having a positive charge will repel another piece which is positively charged, and the same is true of two negative charges; but if one has a positive and the other a negative charge, they will attract each other. When a positively and a negatively charged body are placed near each other, not only do the bodies attract with considerable force, but the charges themselves get as near together as possible by concentrating in the parts of the charged bodies that are nearest together.

Discharge.—If now a wire is stretched across from one charged conductor to another, an electric current flows through the wire from the body that has the positive charge to the one that has the negative charge. After this passage has taken place there is no charge of any kind left. We say that the opposite charges have "neutralized" each other.

Breaking Through an Insulating Material.—Whenever there is a positive charge of electricity, there must also be a negative charge somewhere not far away. The one is never found without the other, and the electricity is trying to get across from the positively charged body to the other. If a cloud is carrying positive electricity, either the earth or else some other cloud is carrying a corresponding amount of negative electricity. If a wire or rod could be placed across from one to the other, the electricity would instantly make use of it to get across; but it does not wait for any wire, it "breaks" through the air that separates them, very much as the water in a pond may break through a dam. Whether it can do this or not depends on the distance it has to jump and the intensity of the charge, or in other words, the "electric pressure."

Electric Sparks and Lightning.—If electricity breaks through the air in this way on a small scale, it is an electric spark. If it occurs in nature between clouds or between a cloud and the earth, it is a lightning flash.

Electric Strain.—Just before it breaks down the air is said to be "electrically strained," for in some ways the behavior of an insulator seems like that of a piece of solid material which is strained and finally broken. After it has broken down, the air is really a conductor, although a rather poor one. When it has cooled off, it again becomes an insulator.

Value of Points.—Besides the discharge that occurs by the electricity breaking through the air, there is a perfectly quiet and harmless discharge that takes place more slowly, from any sharp edged or pointed conductors that reach up toward the cloud and are connected with the earth by a continuous line of conducting material.

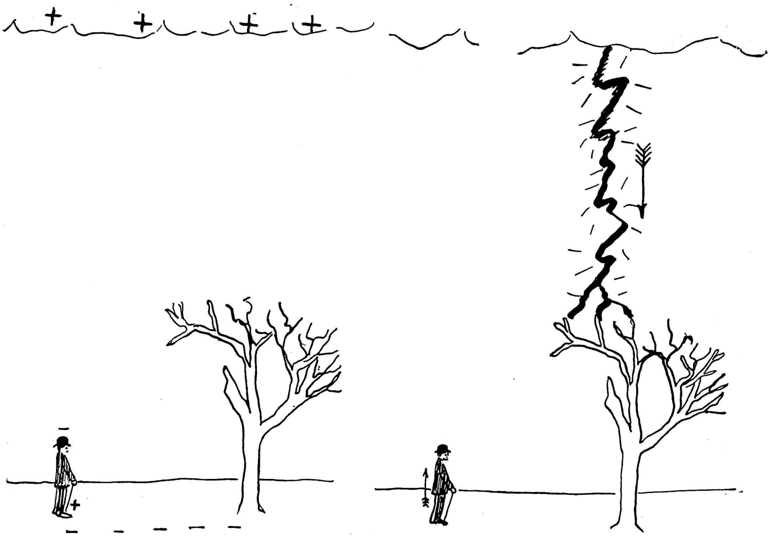
By neutralizing the charge in the cloud in this way a direct stroke of lightning may frequently be prevented. When a point is discharging electricity very rapidly, a faint blue haze appears right at the tip and there is a smell of ozone.

Where Lightning Occurs.—There are probably twenty lightning flashes between clouds to one between a cloud and the earth. The most frequent discharges occur near the front edge of the advancing storm. The places that are most likely to be struck are hill tops and other high objects, such as buildings. Lightning strokes are also more frequent in the neighborhood of bodies of water and over swamps. Where the earth is a good conductor there is more likelihood of lightning than where it is a poor conductor. For this reason moist soils and high ground-water level, as well as the presence of coal or iron ore tend to increase the danger of lightning. Smoke and some kinds of vapor seem to reduce the insulating power of the air, making lightning strokes more probable. The vapor from hay stacks and hay stored in barns appears to have this quality, as hay stacks are notorious for the frequency with which they are struck. A column of hot smoke is believed to form an easy path for a lightning discharge. But the smoke may have a beneficial effect, for the minute particles of soot carry away some of the charge from the earth and neutralize the charge in the cloud, accomplishing in this way the same valuable work as lightning rod points. So while a chimney may be more liable to stroke than surrounding objects of equal height, yet the fact that it is sending out smoke and hot air makes it less likely that there will be a stroke at all. The chimney protects its neighbors better than itself. This presence of numerous chimneys probably accounts to some extent for the small amount of damage from lightning in towns and cities.

Destructive Power of Lightning.—Wherever the lightning discharge goes it produces heat. The poorer the conductor through which it passes the greater the heat. A good metallic conductor of sufficient size will carry the current with comparatively little heating. It will get hot, to be sure, but not hot enough to do any harm. Now when lightning passes through stone and wood it develops great heat because they are poor conductors. If they contain moisture, it is instantly turned into steam and blows them to pieces. Wood is very likely to catch fire if it is dry enough to burn; and metal objects may be melted. When a flash passes from the air into a metal conductor, the conductor is apt to be melted at that point, but the heat which melts it is not produced in the metal, but in the air right next to it.

Shock from Lightning Without Being Struck.—People are very frequently knocked down or shocked when a flash of lightning occurs, and yet it appears afterwards that the lightning did not pass anywhere near them. It would not be unnatural in such a case to feel like accusing them of imagining their sensations, but the experience is not necessarily imaginary at all.

A lightning stroke always results in a sudden change in the electrical condition of the cloud. Usually the charge in the cloud is actually reversed a number of times in a very small fraction of a second. Suppose the cloud over a man is positively charged, and the earth is negative. Since the human body is a conductor, the positive charge in the cloud attracts a negative charge to the man's



Shock Without Being Struck.

Fig. 3. a. Just before stroke, + indicates the presence of a positive charge; — indicates the presence of a negative charge.

Fig. 3 b. During stroke. Arrow indicates the flow of electric current.

head, while the negative charge of the earth draws a positive charge to his feet. Now a lightning flash occurs somewhere near and in an instant the earth becomes positive and the cloud negative. The charges in the man will have to reverse at the same time, which means that a current of electricity passes from one end of his body to the other, and this is enough to give him a more or less violent shock.

The Course Taken by a Lightning Stroke.—The course that a discharge will take is already practically determined before it occurs. Just before a flash between a cloud and the earth the air is under an "electric strain," and this strain is more intense in some places than others. The cloud is more highly charged at some points than at others, and as the mist condenses into rain the pressure keeps rising. The various objects on the earth are more or less charged and here and there are objects which are fairly good conductors. The distribution of electricity in the cloud, the presence of conductors and the presence of charged objects projecting above the earth all have a share in determining certain paths between the cloud and earth where the electric strain on the air is greatest. Then, the air is weaker along some lines than others, due to the presence of impurities and to moisture. These two factors together, intensity of strain and weak spots in the air, determine where the lightning strikes and what course it takes.

Does Lightning Strike Twice in the Same Place?—The saying that "lightning never strikes twice in the same place" is altogether wrong. Numerous examples are known of lightning striking the same place not only twice, but many times. In fact, a place that has been struck once is more likely to be struck again than a place which has never been struck. Of two similar houses, one of which has been struck and the other not, the one that has been struck is in greater danger during a storm, not because it has been struck, but because the same reasons that caused the lightning to select this house in the first place may still be present.

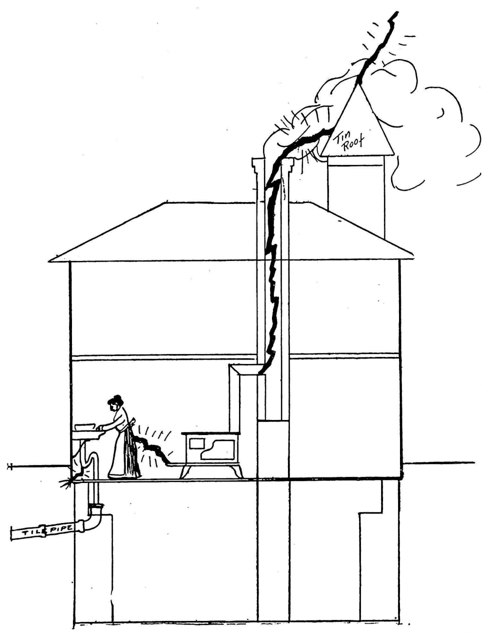


Fig. 4. Example of path taken by lightning.

Behavior of Lightning in a Building.—If lightning strikes a house that it not provided with a lightning conductor, its course is determined by what conductors it can find, by the electric charge on the various objects in its way, and by the insulating strength of the air and other materials that it has to break through. Usually it will be found after the stroke has passed that it has used any conductors that would help it on its way to the ground, jumping from one to the other when necessary at the point where they were closest together. For instance, it may strike a chimney, travel down the soot-covered inside, which is a fairly good conductor, along the stove pipe, through the stove, jump several feet through air to get to the sink, and pass down the drain-pipes to the earth. Another example, is a church, the steeple of which was struck. The lightning made use of a long iron rod used as a brace in the steeple structure. From the lower end of this it jumped to the clock works, which carried it as far as the clock face, where it jumped several feet to the lead flashing in a roof-valley. This lead flashing carried it to the roof gutter, which was metal, and the rain pipes took it to the ground.

If lightning strikes a lightning rod it will in all probability follow the rod into the ground, but if the ground connection is bad it is likely to take other paths. Even in the case of a good ground connection, it must be remembered that there is an enormous difference in electrical pressure between the top of the rod and the ground. This pressure may be sufficient to cause the lightning to jump from the rod to other conductors if there are any near, and send at least a part of the current that way. This is what is called a "side flash," and is of frequent occurrence. A good example of a side flash was a case when a man had a gun leaning against the wall in his house, directly opposite the lightning rod outside. The lightning passed through the wall to reach the gun, and from the butt of the gun struck through the floor to the ground.

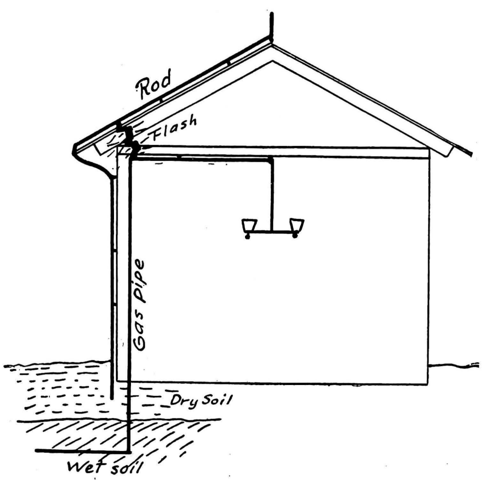


Fig. 5. Example of a side-flash.

Wherever the lightning can travel through metal, and the metal conductor is not so small as to be melted, no harm is done. Wherever it passes through other things it is likely to shatter them. Hence if there is any likelihood of lightning jumping from one metallic conductor to another, a good metal connection should be provided so that the passage will not be attended by damage. Chains of conductors formed in this way must be complete all the way to the earth. For instance, if the roof gutter is connected to the rod it is still more important to provide a good ground connection from the bottoms of the rain spouts. Water and gas pipes have excellent connections with the ground, and if they pass anywhere near the lightning conductor they should be connected with it by metal. If the gas pipes are made of lead, however, they should kept well away from the lightning rod, as the lead may be melted even though there are good metallic connectors to it.

Lightning avoids roundabout paths whenever it can take a short cut, even though the short cut is of poor conductors and involves breaking through considerable air and other insulating materials.

In designing lightning conductors three things must be kept in mind:

1. Lightning is likely to make use of any metal that lies anywhere within reach and may do considerable damage in getting to and from this metal.

2. Lightning has a very strong tendency to split up and go part one way and part another. If the system of lightning conductors provided for it is arranged to permit it to do this, the danger of its taking other courses that were not intended is greatly reduced.

3. Lightning seeks as direct a path as possible. It might be compared to a man who is in a great hurry to get to a certain place. He prefers good roads if there are any, but will not go much out of his way for the sake of good roads, and even cuts 'cross-lots to save a little distance.

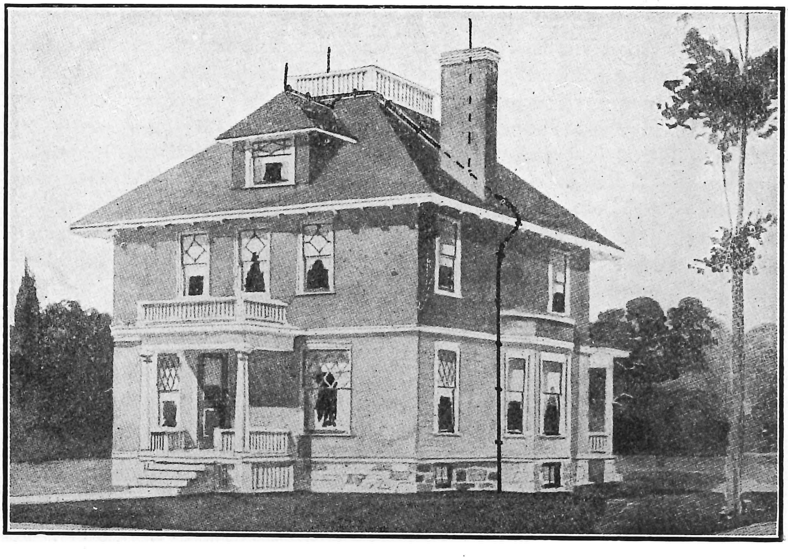
Again, it might be compared to a railroad passenger going to a distant city. If he can take a through train he will use it, but if any time is saved by going part way on one train and then changing cars, he will do that. The destination of the lightning is the ground. If a single continuous conductor will take it all the way, it will use that conductor, but if a more direct route is offered by several disconnected conductors, the lightning is apt to take the short cut, even if it has to make several jumps.

A rule adopted by the Royal Institute of British Architects is, that the length of a lightning conductor between any two points must not be more than one and one-half times the length of a straight line between these same points.

Resistance Not the Only Factor.—The great suddenness with which a lightning stroke occurs causes it to act very differently in a lightning rod from the way the electricity which supplies our electric lights would act. The dangerous "side flashes" that sometimes occur are because the electricity cannot get through the rod as fast as it wants to, and consequently finds other ways to get to the ground. But the trouble the lightning encounters in getting down the rod is not due to the "resistance" of the rod (which depends on the size of the rod and the material of which it is made) half so much as it is due to the difficulty of getting a big electric current started through the rod in so short a time. In this respect it is something like a gun. The tremendous pressure behind the bullet is not necessary merely in order to overcome the friction in the barrel, but to get the bullet started in a very short time.

For this reason the importance of using heavy copper rods, which give very low resistance, has been over estimated. So far as danger of side flashes is concerned, there is little choice between an iron wire 1-8 of an inch thick and a copper rod a half-inch in diameter. (There are, however, other advantages in favor of the large conductors, namely, less danger of their being melted, and longer life.)

The only real way to provide an easy path for the lightning and thus reduce the danger of side flashes, is to use several rods or wires connected together at the top so that the lightning can use all of them at once.



(See illustrations of rodded houses on pages 27 and 28 noting that wherever the lightning strikes it will find at least two ways to get to the ground.)

The farther apart these conductors are placed the better. Two wires twisted together are hardly better than a single one. An inch apart they are considerably better than one, a foot apart still better, and if twenty feet apart they offer hardly more than half the obstruction that a single wire would offer. Two wires placed twenty feet apart are better in this respect than twenty wires twisted into a cable. Three, four or five conductors may be used in this way to advantage, but it is essential that each one be provided with a good ground connection.

Only the Outside of the Conductor Is Used.—There is another effect which results from the great suddenness with which lightning comes on, and which is important in designing lightning conductors. Just as the electric current tends to split up and go down part one way and part another when there are several paths provided, so the minute streams that are flowing in a single rod or wire try to get as far apart as possible, with the result that all the electricity flows close to the surface of the conductor. If the latter is in the form of a round bar the current flows just in the "skin," if the bar is square the electricity crowds into the corners, or if in the form of a flat strip the two edges carry almost all of the current. If, instead of being a solid piece, the conductor is woven or twisted out of a number of smaller wires, the same thing holds true. The outside wires carry all, or nearly all, the current. If the conductor is so woven that the same wire is outside at one point and inside at another a slight advantage may be gained, but in general the current of electricity will cross from one wire to another so as to always keep on the outside.

Large Conductors Waste Material.—From this it is evident that the material in the interior of a conductor is wasted, is just so much dead "filler," and the larger the rod, the smaller the proportion of the material that actually does the work. Thus a very fine wire uses all its material, while a rod a half-inch in diameter would use less than a tenth of the material in it. A thin tube would serve just as well as a solid bar of the same size, so far as conducting the electricity goes, and tubes have been used, but they are frail and difficult to handle. Besides this, the metal in the interior, while it does not help conduct the electricity, does help to absorb the heat that is produced in the outer layers. Since the heat is produced so quickly that the air around the rod can not carry it away in time to prevent the rod from getting hot, this heat must be absorbed by the metal of the rod, and a certain amount of metal is necessary to absorb it.

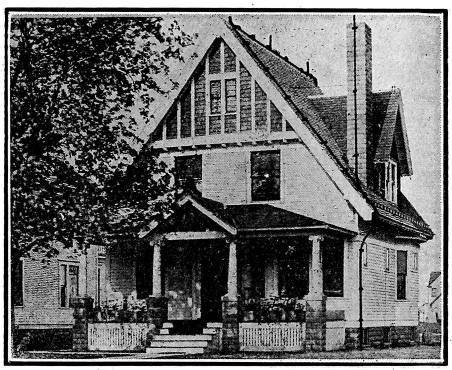
A tube might melt, when a solid bar of the same size would be uninjured.

The only object then of using heavy conductors is to avoid the danger of their melting, and experience is the only guide in determining what sizes are necessary. But if instead of putting all the material into one conductor, several smaller ones are used, so that the current can split up and go part one way and part another, not only is the heat developed in each so reduced that there is less danger of melting, but a larger part of the material is useful in conducting the electricity, and a much easier path offered for the lightning to get to the ground.

Character of the Protection Afforded by Rods.—The protective power of lightning rods is three-fold; first, the preventive effect of the silent discharge from the points; secondly, that the rod, if an actual stroke occurs, will carry the lightning harmlessly to the ground; and in the third place there is less danger of persons or animals inside the building being injured by the shock (described on page 14) that is sometimes received by those who are not actually struck. The value of the points is universally conceded. They cause a gradual discharge that reduces the chances of a direct stroke occurring, though they can not always prevent a stroke. It takes time for the points to get in their work, and there are frequent cases where the conditions that cause a stroke come about so suddenly that no amount of pointed conductors would prevent it. Such a condition arises when the cloud over a building remains unchanged for some time and then is suddenly charged with electricity by a lightning flash between it and another cloud.

Examples of buildings struck in spite of pointed conductors are no argument against the points.

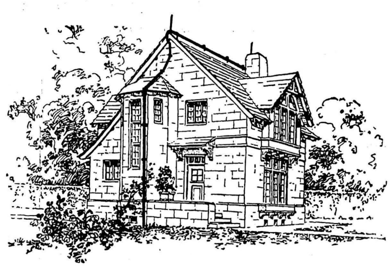
Do Lightning Rods Attract Lightning?—The question will naturally arise whether a conductor reaching up toward the cloud does not actually invite the lightning stroke. The answer is that it probably does to some extent. But it attracts the lightning only to itself. It can never in any case make the danger of some other part of the building being struck greater than without the rod. A number of cases are known in which



lightning had struck the rod and the people within the building had known nothing about it exceut that somewhere near by there had been a brilliant flash of lightning with loud thunder. The discovery next day that the points of the conductor has been fused showed what had happened. If the rod, however, is not such that it can take care of the discharge harmlessly when it is struck, it may be worse than nothing. But the question of whether the rod invites the lightning, makes a stroke more likely than before or not, is of minor importance. Experience has shown conclusively that it accomplishes its purpose, and that it is very rare indeed for a properly rodded building to be damaged by lightning.

LIGHTNING RODS AS INSURANCE.

Degree of Protection Afforded.—The question whether lightning rods afford protection was discussed in the introduction, and it was seen that the experience of the Farmers' Mutual Fire Insurance Companies indicates that rodding reduces the danger of lightning stroke to a small part of what it was before.



Wherever extended observations have been taken and accurate records kept the experience has been the same. In the province of Schleswig Holstein in Europe, rods are used very extensively, yet the records of fire insurance companies between the years 1870 and 1878 showed that while 552 buildings altogether were injured by lightning, only four cases were reported of injury to buildings that were provided with rods, and these rods were not in good condition.

If a building is equipped with a well designed system of lightning conductors the danger from lightning is so exceedingly remote that the claims of many lightning rod companies that "No building furnished with our rods has ever been injured," may very well be true. It may also be true that companies can afford to guarantee that no losses will occur on buildings which they equip with rods. It is to be doubted, however, whether such guarantees are in such a form that money could be legally collected from the companies in case of loss by lightning.

Extent of Damage from Lightning.—Having seen that danger may be reduced to practically nothing by good conductors, we may consider the question: "How serious is the danger without lightning conductors? Is the danger great enough to make it worth while to spend the money for conductors?"

These are the questions which are left to the judgment of the owner. He must decide according to his own feelings, his experience and observation of destruction in his vicinity, and such knowledge as he has in regard to the special conditions that make the danger to his buildings greater or less than to other buildings. A few facts are given here that may assist him in deciding the question wisely.

In cities and towns ordinary buildings are in so little danger that lightning rods are rarely installed. In villages the danger is greater; considerable damage is done in smaller towns, but not nearly so much as in the country. The isolated buildings on farms are by far the greatest sufferers from lightning. Some statistics have been gathered which seem to indicate that the danger from lightning is four to five times greater in the country than in the city.

The reports of the Farmers' Mutual Fire Insurance Companies of Missouri give the following figures of losses paid out during the three years, 1909 to 1911:

Year.	Total Losses.	Losses from Lightning.
1909	$237,202.38	$29,755.23
1910	281,726.37	97,361.39
1911	341,471.04	91,678.95
Total	$860,399.69	$218,795.57

From this it is seen that one-fourth of all the losses are due to lightning. The total cost of insurance comes to about 28 cents per year on every $100.00 worth of insured property. Since one-fourth of the losses are due to lightning, it would cost in the neighborhood of seven cents per year on every $100.00 worth of property, to insure against lightning alone.

This figure, however, does not correctly represent the risk to unrodded buildings. Seven cents per $100.00 is the cost of insuring rodded and unrodded buildings indiscriminately, whereas practically all the damage occurs to buildings without rods. Since the Farmers' Mutual Companies make no reduction in rates at present in favor of buildings protected by conductors, the rodded buildings are charged more than enough to pay for their own losses, while unrodded buildings pay less than the cost of their own insurance. If the unrodded buildings were charged a rate that would pay for their own losses, this rate would have to be considerably higher than seven cents per $100.00. It is impossible to say what proportion of the buildings insured had lightning rods. If 70% of the buildings insured were without rods, and had to pay a rate that would cover the cost of insuring them this rate would have to be 10 cents per $100.00 instead of 7 cents.

The figure, 10 cents per year for every $100.00 of building value, may perhaps be taken as a fair average of the risk to unrodded farm buildings throughout the State. To state it differently, there is one chance in a thousand that your unrodded building will be completely destroyed by lightning within the next year.

Based on this estimate you would be warranted in spending $1.00 a year to protect a building worth $1,000.00. Since $1.00 is the annual interest on about $20.00, it would be worth while to spend $20.00 on a lightning rod for a building worth (with its contents) $1,000.00, $40.00 on a $2,000.00 building, and so on.

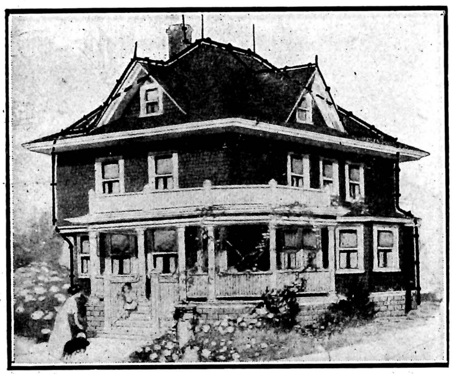
Since the insurance companies make no difference in rates, it would seem at first sight that it would be better policy and cheaper to simply keep the building insured and let the insurance company take the risk. In some cases this is true, but there are many considerations that make it worth while to equip buildings with rods, even though it is a more expensive kind of insurance than that offered by insurance companies.

The Principle of Insurance.—The usefulness of insurance is based on the fact that a man can better afford to bear a slight loss that occurs regularly and that he can figure on, than to sustain a single heavy loss that he can not foresee. The small losses are to be sure, a drain on a man's resources, but a sudden great loss may rob him, not only of his property, but of his means of earning. A barn burned may mean not only the loss of the barn, but a crop ruined for lack of space to store it. Horses and tools missing when they are in greatest demand may mean heavy losses in the crop.

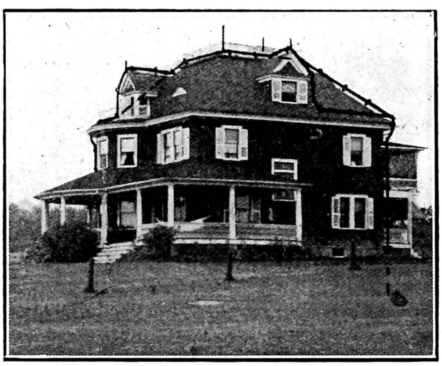
These things are not paid for by insurance companies, neither will they repay even the full value of the building itself and what was in it. Hence an additional insurance may be worth while.

So valuable is it to a man to eliminate chance, and to know beforehand exactly what expenses and losses he will have to meet, that it would pay him to insure his property even if the insurance company charged twice as much as it cost them. Fortunately this is not necessary, as insurance can be had nearly at cost. The less property a man has the more he needs to insure it. The millionaire can afford to be his own insurance company, but the farmer with a single house and barn can not.

Two Kinds of Insurance.—Insurance against losses may be had in two ways, either by spending some money in order to prevent the loss from occurring, or by contracting with an insurance company to have the company stand the loss if it does occur. The first kind of insurance might be call **preventive,** and the second **compensating.**



Preventive insurance may or may not be more expensive than the other, but it is more valuable. Compensating insurance never repays to the full extent of the damage, it **reduces** the loss to the individual, but does not prevent it. He still loses something and the losses that were not and could not be covered by the policy may be serious.



Insurance which pays for prevention, on the other hand, makes it unnecessary that the owner should bear any loss beyond the cost of the preventive measures. Besides this, there are things that can be insured by this method, for which the compensating insurance is altogether inadequate. A few thousand dollars is poor pay for the loss of a life. A life insurance policy will not take the place of a good doctor. Yet a wise man makes use of both. Many a house has been struck and some members of the family killed. Fire insurance companies do not repay those that are left for what they have lost, but lightning conductors might have prevented the loss.

Where Protection Is Most Needed.—To illustrate the cost of insurance against lightning we used the figure 10 cents per $100.00, or one chance in a thousand of complete destruction each year, but this estimate is an average for the entire State, and must not be taken as correct for all places. The danger may be much less in many places and may be five to ten times as great in others. Many counties showed averages twice as high as that for the State. The people living in a locality are perhaps the best judges of whether lightning damage there is unusually heavy or not. In hilly country thunderstorms seem to follow definite courses, so that certain places are visited by storms much more frequently than others. Storms are apt to travel along over valleys, over rivers and over lakes and swamps, in preference to other places, and for this reason buildings near such places are in greater danger. Build'ngs on hillsides and also large structures in the open country that stand out by themselves are especially likely to be struck by lightning. Barns in which large quantities of recently cut hay are stored are believed by many to be more in danger from lightning than at other times.

Large trees close to a house may or may not make the house safer than it would be without them. It is not wise to rely on them as affording much protection.

Summary.—To state briefly the considerations which determine what expenditure would be justified in equipping buildings with conductors, or whether they should be equipped at all, the following questions must be settled:

1. What is the chance of injury to the building?

2. Is it sufficient to insure it against lightning in a fire insurance company?

3. What losses might occur in case of lightning that would not be covered by the policy?

4. Does the building at some times of the year represent such a large part of your property that its destruction would be a very serious matter, ever though most of its value were paid you in cash?

5. Does your fire insurance company make any lower rates on buildings that are protected by rods?

6. Does the building contain persons or things whose loss could not be compensated for in money?

7. Would the personal satisfaction of knowing that your property was in no danger from lightning be worth more to you than simply to know that the loss would be refunded in cash?

It was seen that where storms are not unusually frequent lightning rods may be a somewhat more expensive form of insurance than the kind which insurance companies afford, and if the building is one whose loss would do no great harm beyond the cost of rebuilding, it would probably not pay to provide it with lightning conductors.

If, on the other hand, a lightning stroke would mean loss, either of life or property which would not be repaid by the cash value of the policy, the building ought to have both kinds of insurance—lightning conductors as well as fire insurance policy. This would be especially true of tall structures that are likely to be marks for the lightning, and of buildings situated in places where storms are frequent.

ARRANGEMENT OF CONDUCTORS.

In order to protect a building from lightning, lines of metal conductors must be run from the prominent points of the building, as directly as possible to the ground. Conductors should run along the roof ridges and up above the tops of cupolas and chimneys. If the roof is flat or has small pitch, conductors should be run along the eaves. Next to chimneys and cupolas the points most in danger are gable ends and dormer windows. The conductors on the roof must all be connected together and run down to the ground at several places, say at the corners, and buried deep enough to ensure an easy path for the discharge to get away into moist soil. If a metal roof is used it must be connected with the ground by wires and no further conductors are necessary except at chimneys, where a short rod should be run up a foot or so above the top, and should be soldered to the roofing at the bottom. Soldered joints must be so made that even if the solder were melted the parts would be held together otherwise, as by staples or wire.

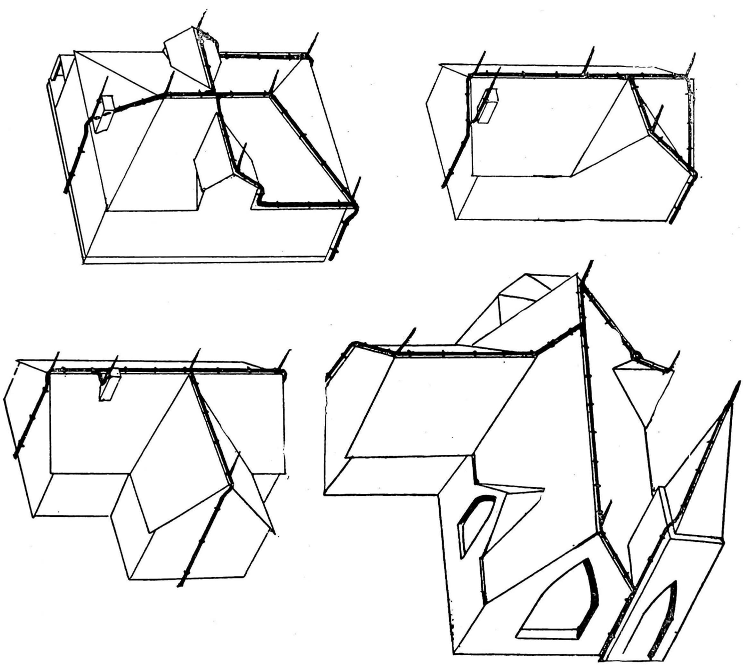
If the rain gutters are of metal they will serve as a conductor as long as they are in good condition. The tin rain spouts will carry the discharge toward the ground as far as they go, and a good connection must be made to them at the bottom, with conductors that run well into the ground.

It is not uncommon to use sheet metal flashing along the hips and ridges of the roof and also in the valleys in order to insure a tight roof. If the lines of metal formed in this way are unbroken, they form in themselves a good system of lightning conductors, provided they are connected at their ends to rods running to the ground. It is best, however, not to let this flashing or the rain gutters and spouts take the place of rods, except on less exposed parts of the building.

The tin roof of a cupola should be connected by several stout wires to the tin roof below, or if the main roof is of shingles or slate, a grounded rod should run direct to the cupola. Ornamental iron work on a roof should be connected to one or more rods leading to the ground.

In short, all metal work on the roof, except very small pieces, should be made a part of the system by connecting it to the other conductors. The connection to any piece of metal should be at its lower edge or end.

Some illustrations are given showing good arrangements of rods for several styles of houses. The general idea is to cover the



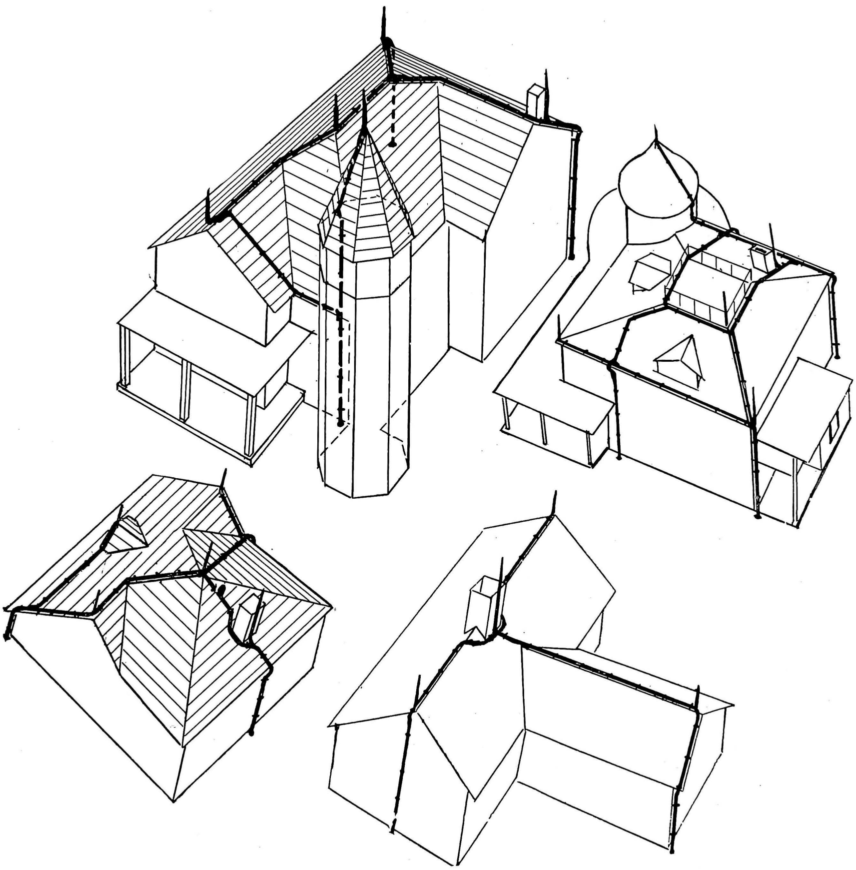


Fig. 7. Arrangements of Rods.

most exposed points in such a manner that from whatever angle a cloud should approach, the point on the building nearest the cloud would be covered by a conductor. It is also aimed to so connect the rods together that the lightning can find several paths to the ground at the same time; to get the verticals that lead to the ground well separated, and to have the paths to the ground as direct as possible. There are three factors which may make it necessary to modify any scheme of conductors:

1. All rods must be kept well away from gas pipes, especially

if the gas pipes are of lead.

2. Rain spouts or other conductors may take the place of some part of the lightning conductor system.

3. It may be necessary to arrange the conductors a little differently in order to reach and connect to other metal work on the roof.

Rodding a Tree.—Where a house is overtopped by a large tree, the rod may be placed on the tree instead of on the house. The rod in this case must be of as good material and just as carefully grounded as if it were on the house. It should run out one of the limbs that reaches over the house, but should be kept clear of the house by as much as ten feet if possible. The rod should not be attached too tightly to the tree, and should have a little slack, to allow for growth in the tree.

The Ground Connection.—The entire rod may be rendered useless by a poor ground connection, and for this reason great care should be taken with this important part of the system. The elec-

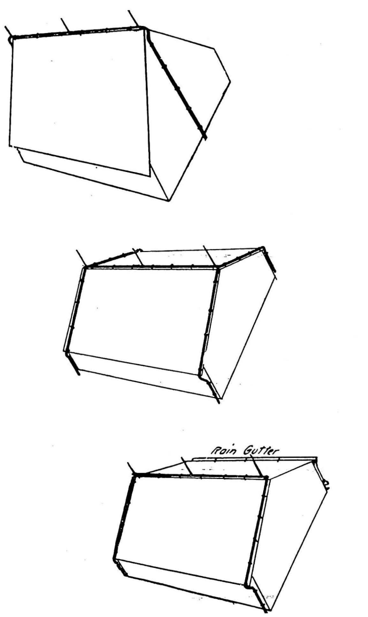


Fig. 8. A steep roofed building needs no conductors at the eaves. If the roof is flat, the eaves need protection, especially at the corners. The rain gutters may be sufficient protection for the eaves.

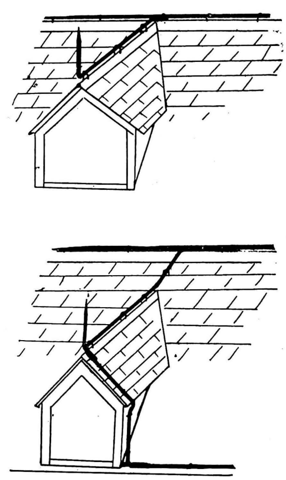


Fig. 9. If the ridge of a dormer or wing is short, and on the same level as the main ridge, it may be taken care of by a branch from the main line of conductor, as shown in the upper figure. But if it is below the level of the main ridge, or is more than about twelve feet long, a more direct path to the ground should be provided.

tricity must get to the ground water, or at least to wet soil. It can pass through moist soil, although this is a very poor conductor; but dry soil is such a good insulator that a lightning stroke on one occasion was known to travel 900 feet along a water pipe that was buried in dry soil, without being able to get away into the ground. The lightning reached the pipe in a house that was struck, went along the water pipe and did some damage to a drinking fountain 900 feet away.

You can not safely trust to luck that the ground will be moist four feet down. You must know from having dug down until you reached damp earth, and this ought to be done after a considerable period of dry weather. If you do not wish to wait for dry weather, and do not know what depth is necessary from previous observation, you should go deep enought to be on the safe side. In most places seven feet ought to be enough.

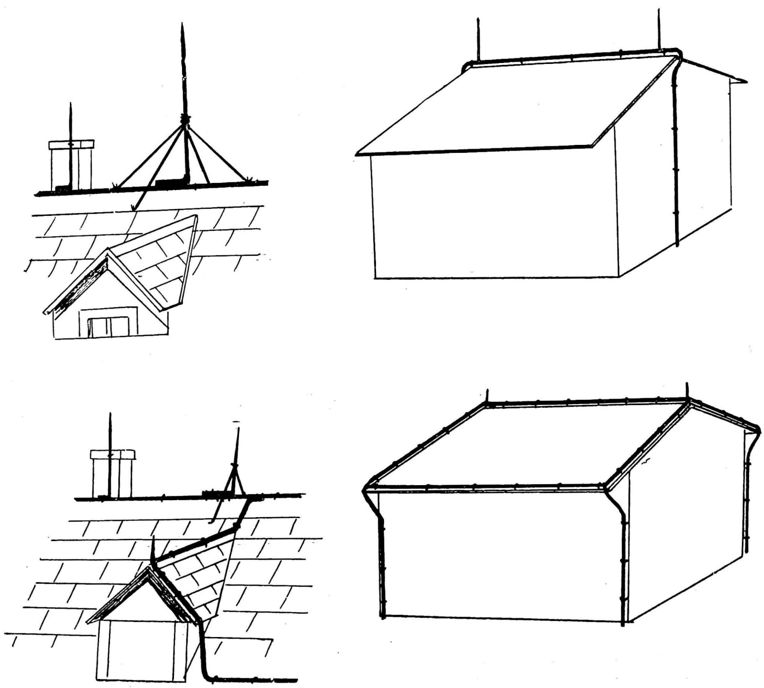


Fig. 10. It is largely a matter of choice and of appearance whether to use tall terminal rods, or to run extra lines of conductor to neighboring points that are somewhat exposed. But it is not well to rely on other near by rods to protect a chimney that is in use during warm weather.

Next in importance to reaching permanently moist earth is the problem of arranging the conductor so that the surface presented to the soil will be sufficient to allow the discharge to get away easily. The amount of surface of metal in contact with the soil is not the only thing to look out for. The electricity from the conductor must be able to spread out quickly into the soil. For instance there is no value in obtaining a large surface by burying a number of plates close together. The current flowing from one part of the conductor must not crowd the current coming from another part or from another conductor. For this reason two rods driven into the ground a foot apart are very much better than if driven six inches apart. A hole 18" square filled with coke is a very good ground connection, much better than that made by driving a 1½" galvanized iron pipe into the ground to the same depth; but two such pipes driven three feet apart and connected at the top are nearly as good as the hole full

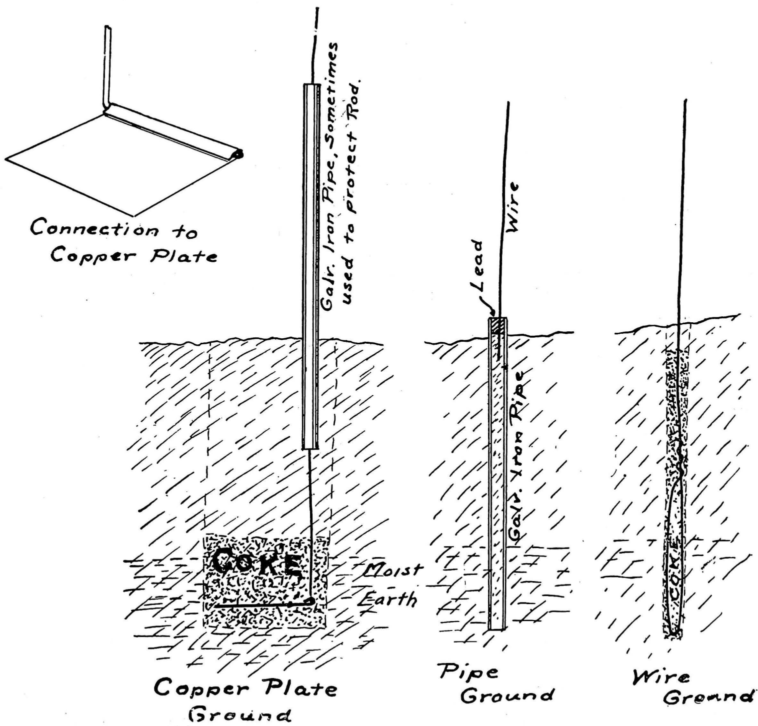


Fig. 11. Ground Connections.

of coke. Likewise the pipe is better than a wire 1-8 inch thick buried to the same depth; but two such wires six inches apart are as good as one pipe, although their actual surface is less.

All three kinds of ground connections have their places. The carefully made coke and copper plate ground is the safest and most permanent, and all large and important buildings should have at least one and preferably two ground connections of this kind or else a good connection to a water pipe. The other conductors on the same building may run to pipe grounds or to wire grounds.

Water Pipe Grounds.—This is the best of all ground connections and should always be used where there is a water pipe running to the building. A metal pipe from a well is as good as any water pipe if it is buried in the ground for some distance, but if it runs straight down the well without giving the lightning a chance to escape before it reaches the water, the well pipe should not be used.

Buried Plate.—Dig a hole 18 inches square and deep enough to get at least two feet below permanently moist earth. The wire that forms the lightning rod should be bent at right angles about 17 inches from the end. Cut a piece of sheet copper 17x18 inches and bend the edge over the wire so as to grip it tightly. The joint can then be heated with a blow-torch and solder run in. It would be well to use sheet copper as heavy as No. 22 gage, weighing about 14 oz. to the square foot for this purpose. Get about two bushels of charcoal or coke (the charcoal is preferable) and crush it sufficiently so that the powder and small lumps will fill up the spaces between the large lumps. Make a thin bed of the charcoal under the plate and put the rest on top. Pack the charcoal hard, and fill up the hole.

Instead of using a copper plate the wire itself may be coiled so as to present a large surface to the charcoal. The cost of such a ground should be about as follows:

Portion of rod below ground	$ .25
Copper plate	.50
Coke or charcoal	.25
Labor ..(Depends much on kind of soil and depth)..	1.00
	$2.00

Pipe Grounds.—Pipe grounds are neither as permanent nor as reliable as grounds made by burying copper plates in coke, but are sufficiently good for less important buildings or for some of the rods on a large building, if the most important rods of the building are furnished with copper plate grounds. By "most important" we mean the rods that come directly from the most exposed parts of the building.

Except in stony soil, one inch, to one and one-half inch galvanized iron pipe can usually be driven seven feet into the ground without great difficulty. If the soil is very sticky it may be easier to start the hole by driving a large pipe say three feet and then pulling it, and driving the smaller pipe the rest of the way.

To make the connection with the rod, insert the wire or rod a few inches into the top of the pipe. Fill the pipe with earth up to within an inch of the top and pour in melted solder or lead around the wire till it is flush with the top.

Care must be taken to protect the wire and place it where it will be secure from injury. It might in some cases be advisable to dig a hole and drive the pipe down until its top is a foot below the surface of the ground. The wire can then be run horizontally toward the wall and brought out of the ground right against the building where it will be secure. If there is any danger of any one's digging around it, the wire underground should be covered with a little concrete.

Pipe grounds ordinarily are very easy to make, but should not be relied on for more than about 10 years. The pipe will cost from 10 cents to fifteen cents a foot. On the average the cost might be:—

7 feet of pipe at 12cts.	$ .84
Labor	.30
Lead or solder	.05
	$1.19

Wire Grounds.—If a post hole auger is available or if the soil is such that a pipe can easily be driven and pulled out leaving a clean hole, wire grounds are the cheapest thing that can be used, and if carefully made should be nearly as good as pipe grounds. Since a good piece of copper wire as large as No. 6 B. & S. will last underground indefinitely, it is in this respect better than the galvanized pipe. The wire should be bent back to form a loop about 2½ feet long, the end being wrapped a few times around the main wire. Make the loop narrow enough to enter the hole easily, and be sure that it reaches the bottom. Fill in around the wire with powdered coke or charcoal and ram it down tight.

A ground of this kind will do for the less important rods on a large building or for any rod on a small building. It should cost not more than about 25 cents for the copper in the buried conductor (if No. 4 B. & S. wire is used) and about an hour's labor.

In Case of Rock.—In case a house is built where there is a ledge of rock a few feet below the surface of the ground, there is frequently some difficulty in getting a good ground connection. A water pipe connection should be used if possible. If a deep seam in the rock can be found make a ground connection in this. If necessary run the wire some distance in a trench to get to a good place for a ground connection. If nothing but solid rock can be found, dig a trench down to rock and some twenty feet long for each rod. Run a wire in a three inch layer of crushed charcoal or coke the full length of the trench.

Grounds Made Before the House Is Built.—If it is decided that a new house is to be rodded, figure out where the ground connection will come, before the foundations are put in. Run a No. 4 or No. 6 wire buried in crushed charcoal six feet along side of the footing in the bottom of the foundation trench and bring the wire up either outside or right through the concrete or masonry. The wire may continue inside the building all the way up to the eaves if desired, or it may be enclosed in the wall or buried in brick or stone work

Points or Terminal Rods.—If the rods run all the way up to all the prominent points of a building it is not necessary that they project above in the form of points if there is any serious objection to the points on the ground of appearance. If the points are omitted, conductors should run along all ridges and eaves, and to the top of each chimney where they should be attached by running a wire all around the chimney as close to the top as possible.

On most buildings, however, lightning rod points are not objectionable in appearance, they may be even decorative, and their presence adds to the security of the building by still further reducing the chance that lightning may strike anything but the rod. Besides this the points assist in preventing a lightning stroke from occuring at all. There is some difference of opinion as to the advantage of placing a number of sharp points on one terminal rod. The silent discharge from two points would be twice as great as from one point, if they did not interfere with each other, but the effectiveness of a point depends on its projecting above, and being kept away from other conductors. Hence is is doubtful if the advantage of placing a number of points together on a single rod is sufficient to justify the extra labor or expense.

The pointed terminal rods are ordinarily made from two to four feet high, and should be placed on all prominent points of the building and every 20 feet on long ridges. They should be made of copper and filed to a sharp point at the end. No. 3 B. & S. wire should be brought to a point in about 3-4 inch, No. 0 wire in 1 inch, and No. 0000 gage wire in 1 1-4 inches. The terminal rod needs to be of heavier material than the main conductor, first to secure stiffness, and secondly because it is more likely to be the part actually struck and hence is in more danger of being melted. "Hard drawn" wire should be obtained if possible for terminal rods since it is stiffer than the soft drawn, but the soft drawn wire is better for the main conductors. No. 2 or No. 3 wire may be used where it does not project more than ten or twelve inches above the last support. It might be used on such places as flag poles and chimneys.

No. 0 wire can be used where the rod does not project more

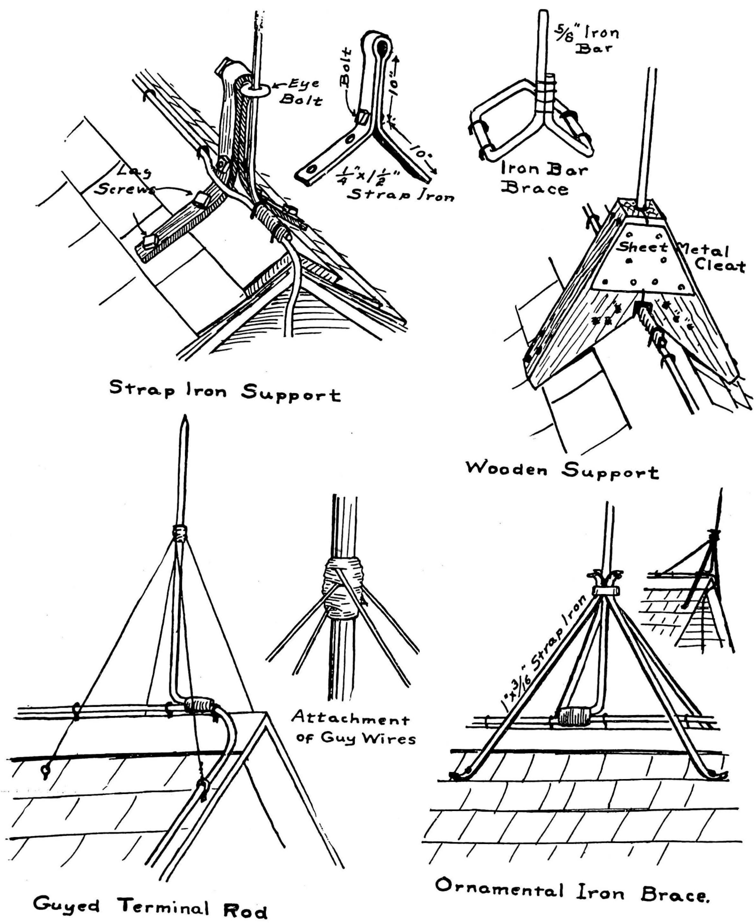


Fig. 12. Supports for Terminal Rods.

than 18 inches, and No. 0000 is stiff enough to stand about 24 inches above the last support.

Supports for Terminal Rods.—Several forms of supports are shown in Fig. 12. The strap iron support can be made up at a blacksmith shop and fastened to the roof with lag screws, care being taken to locate it directly over the rafters. It would be strong enough to support a rod four feet high.

The rod may be supported by wooden bracing. The only objection to the wooden support is the difficulty of giving it a good appearance.

If the terminal rod is fastened well at the bottom and braced by four guy wires, no further supports are necessary. A few small notches are filed in the rod about a foot from the top, or a small hole may be drilled and a pin put through. Two wires are wrapped tightly around the rod, above the pin or in the notches, leaving four ends three to five feet long as may be needed. No. 12 wire is a good size for the guy wires. The joint at the rod should be made more secure by wrapping a few turns of small wire on the outside, twisting the ends together and filling the whole joint with solder. The lower ends of the guy wires may be fastened with staples or screw eyes in the roof. This is probably the cheapest and strongest way of bracing terminal rods, especially the taller ones. The rod needs to be set back about a foot from the gable end if it is to be braced by guy wires. No. 0 wire would be heavy enough for rods braced in this way. Supports made especially for lightning rod terminals can be bought from dealers at a reasonable figure.

The Main Conductors.—The rods running from the terminals or points to the ground connections may be fastened to the building with large galvanized iron staples or with screw eyes. There is no object in insulating the rod from the building with glass or porcelain. There should be a fastening at every two and a half feet, on horizontal runs and every four feet on vertical runs. It is possible that a heavy lightning discharge might heat a small rod hot enough to set fire to woodwork. For this reason it is recommended that the rod be kept clear of wood in places where the wood is likely to be very dry and where a fire might gain considerable headway before being discovered. On the outside of the building, however, it is not usually considered necessary to keep the conductor away from the woodwork, since a fire from this source is very unlikely, and would probably be extinguished by rain if it should start.

If, however, the owner wishes to take every possible precaution, it is suggested either that he use a heavier conductor (say No. 2 or No. 3 B. & S. Copper wire) or else that he use some form of support which will hold the wire out from the wood work by about an inch, and that he place the supports not more than two feet apart. A few examples of suitable supports for this purpose are the double staple, porcelain cleat, and the screw eye.

Where appearance is not of prime importance, fasten the rod to woodwork with staples. Drive two staples side by side, one to hold the wire out from the building, and the other to fasten the wire, as shown in Fig. 13. The wire passes outside the first staple but under the second.

Porcelain cleats, such as are used for inside electric wiring, make very neat and satisfactory supports, but are more expensive

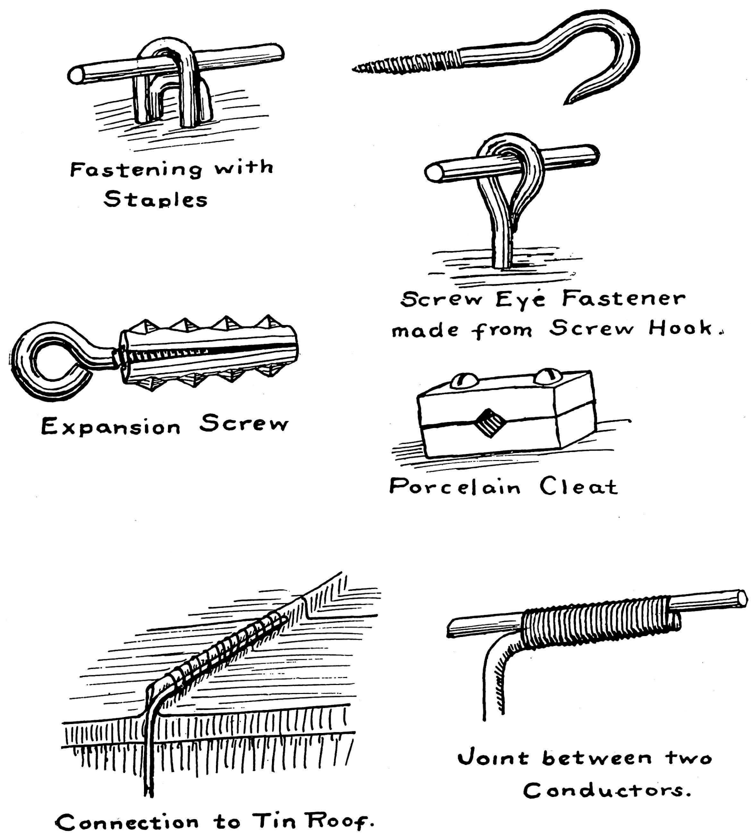


Fig. 13. Methods of attaching conductors to buildings.

than the other supports mentioned, costing in the neighborhood of $2.00 per hundred without screws.

Screw eyes are about as satisfactory in appearance as any support. Instead of buying screw eyes however, get No. 8 screw hooks (preferably brass) screw them in place, slip the wire under the hook and bend the hook shut around the wire. If regular screw-eyes are used they will either have to be screwed in place and the wire threaded through, which is likely to be difficult, or else the eyes may be bent open before putting them in place. Then the eye can be bent shut again around the wire as in the case of the screw-hook. Besides saving part of this labor, the screw-hooks have the advantage that they are made with longer shanks than the screw-eyes

Expansion eye-bolts are useful in fastening to brick or stone.

Rods may be run inside the building, or concealed in the wall if there is any good reason for doing so. The objection to enclosing them in a wall is that they are not open for inspection, and that a fire (if by any possibility one should be started) would not be discovered as promptly as if the rod were in the open. On the other hand the rod is protected from theft and from mechanical injury by enclosing it. The above objections do not apply to stone, brick or concrete walls. If a rod is to be placed within a wooden wall, it should be wrapped well with asbestos paper, and the paper securely fastened in place with wire, wherever the rod passes through a board, or where there is any possibility of its coming in contact with any wood. Here again the necessity of keeping the rod from touching wood, depends on the size of the conductor, but instead of using a large conductor for such places as inside a wall, where the rod is concealed, run an extra No. 4 conductor, parallel with the main line and wrapped about it at both ends, so that if either wire should be broken or cut the other would serve the purpose. The spare wire should be attached to the main conductor below ground, and should reach up above the place where the rod is concealed, and connected in again there. Another good arrangement is to box in the space where the rod is and fill up the form with concrete or else with dry sand.

It is usually necessary to take some care to protect a rod from theft. The copper is of some value, and the part of the rod near the ground is very easily cut and carried away. Painting the rod will help by making it less conspicuous. On stone or brick buildings it may be partly concealed by vines. The copper-clad wire, described later, has the advantage that it is very tough, and that its value as junk is almost nothing. The most common way of protecting copper rods from thieves, is to enclose the rod in a galvanized iron pipe reaching about two feet below ground and eight feet above. The pipe must be securely fastened to the building. Another way is to wrap the rod with asbestos paper and nail a grooved plank over it, running a spare wire alongside as described above. The rod may be run inside the wall, or a small form may be built around it and filled with concrete, first driving a number of stout nails or screws into the wall for the concrete to hold to.

In arranging the conductors avoid all sharp bends. Use long easy curves or "goose-necks" in going over the eaves, but if the overhang is considerable it is better to bore a hole and go straight through close to the wall. No joints should be used if they can possibly be avoided. The house should be measured before the material is ordered, and the order should give the lengths required, adding a few feet for good measure. Let the Supply House do the cutting if possible. Fasten the copper plate to one end of the wire and bury it in charcoal as already described. Without cutting the wire arrange it over the building as it is to go, and make the ground connection on the other end. Thus a single conductor should run from the buried copper plate at one corner of the building, up to the eaves, to the ridge, along the ridge to the other end and down to the other buried plate, without a single joint or splice.

Joints.—Where connection is made between two lines or rodding the joint should be made by wrapping the two together with smaller copper wire (say No. 19) and filling the cracks with solder. Be sure that all wires are clean and free from grease before attempting to solder. Treat the surface with acid used by tinners.

Material for Rods.—We have so far spoken of the conductors as "wire." Solid wire is about the cheapest form in which conductors can be had, and is easy to handle, and for this reason is the material usually preferred for home-made rods. There are other forms of conductors on the market, however, which are worthy of notice and which will be mentioned here.

The following table shows the sizes, weights and cost of a few sizes of wire that might be used.

Material.	Size B. & S. Gage.	Diameter Inches.	Weight per 100 ft.	Cost per Pound.	Cost per 100 ft.
Solid Copper Wire	19	.035	0.4	25c	$ .10
	12	.081	2.0	22	.44
	10	.102	3.1	22	.68
	8	.128	5.0	20	1.00
	6	.162	7.9	20	1.58
	4	.204	12.6	20	2.52
	3	.229	15.9	20	3.18
	2	.257	20.1	20	4.02
	1	.289	25.3	20	5.06
	0	.325	32	20	6.40
	00	.365	40.2	20	8.04
	000	.41	50.8	20	10.16
	0000	.46	64.0	20	12.80
Aluminum Wire	10	.102	1.0	45c	.45
	8	.128	1.5	45	.68
	6	.162	2.4	45	1.08
	4	.204	3.8	45	1.71
	2	.257	6.1	45	2.75
	4	.325	9.7	45	4.36
	0000	.46	19.4	45	8.75
Copper Clad Steel Wire 30% Conductivity	10	.102	2.9	16c	$ .46
	8	.128	4.5	16	.72
	6	.162	7.2	16	1.15
	4	.204	11.5	16	1.84
	2	.257	18.5	16	2.95
	0	.325	29.2	16	4.68
Galvanized Iron. Wire E. B. B.	Birmingham Gage No.				
	12	.105	3.1	5c	.15½
	10	.135	4.9	5	.24½
	8	.162	7.2	5	.36
	6	.192	10.2	5	.51
	4	.225	13.8	5	.69
	3	.244	16.3	5	.82
	2	.263	18.9	5	.95

The above prices are approximate only, but will serve as a guide and to help in deciding what material to use. Copper changes considerably in price from month to month. Costs on special forms of lightning conductors will have to be obtained directly from the manufacturers.

Size of Conductor.—It has been the custom to use heavy copper conductors in order to avoid danger of their being melted, and also to reduce the danger of side flashes. The value of large conductors in respect to the latter point has been overestimated. The danger of melting and the mechanical strength of the rod are the principal points to consider. Records of melted rods are so few that it is impossible to say just what is the smallest size that will carry off a fairly heavy lightning discharge. No ordinary rod can be depended on not to melt at the point where it is struck, for the heat developed where the lightning passes from the air into the rod is very much greater than the heat developed in the rod itself. It seems probable that a No. 8 copper wire will conduct any ordinary lightning discharge without melting in two. This much is certain, even if a conductor should melt, it would have done its work before melting, so far as that stroke was concerned. As long as the conductor is there the lightning will pass through it. By the time it is melted a path is already formed and the electricity would continue to flow over the same course. There are cases on record of wires that directed strokes in this way, although the wires themselves had disappeared. This does not mean that it is well to employ a conductor that will melt, but it goes to show that even a conductor which melted during a heavy stroke would be better than none.

There are four ways in which too small a conductor is dangerous:

1. If it melts it may possibly cause the stroke to seek some other course which it would not if the rod had remained intact.

2. The great heat developed where the rod melted in two would increase the danger of fire.

3. If a second stroke should occur during the same storm, the house would be unprotected.

4. If the melting should not be noticed and the rod not repaired, the house would be unprotected in future storms.

It seems advisable to keep on the safe side by using conductors considerably heavier than that which is thought to be just sufficient not to melt.

In the arrangements of rods recommended in this bulletin there are (except for short distances) always two or three paths for lightning to get to ground. With such an arrangement it is believed that No. 6 copper wire would be safe, but in order to take no chances No. 4 is recommended for all the rods running to the most exposed parts of the building, while No. 6 might be used for cross connections and for conductors on places that are less in danger, such as eaves. It will be seen by consulting the table that the cost of No. 4 is only about $1.00 more per 100 feet than No. 6, and the amount saved by using the smaller wire for the main lines of conductor is not enough to make it wise to economize in this way.

If other copper conductor than the wire is used it should have at least as much weight per foot as the wire recommended here.

Other Materials for Rods.—Copper lightning rods have been made in many different shapes, such as square bar, fluted and twisted rods, flat strip, stranded cable, round woven cable, and flat woven cable. These forms have some advantages, but usually increase the cost more than they increase the efficiency of the rod.

There is no special virtue in any particular form of rod. Lightning does not travel better in a spiral. The only laws that lightning follows that have any thing to do with the shape of the conductor, are the laws that have been already stated in regard to the tendency to concentrate at the surface or edges or corners of a conductor. (See Page 19). The only purpose in making a rod any other shape than round, is to economize copper, and perhaps to make a conductor that is more easily installed.

A comparison will be made between a copper wire rod and some of the other forms, assuming that they all contain the same amount of copper per foot. Flat copper strip can be obtained from some electric companies and wire manufacturers.. It offers somewhat less resistance to the electric current than a round wire of the same weight, but is no better in this respect than two smaller wires placed an inch or two apart running parallel. The strip is somewhat more easily damaged than the round wire, and is awkward to install in some places.

Square or fluted rods, twisted or plain, have very slight advantage over round wire, and are hard to make good connections and joints with.

Copper wire rope or cable is somewhat easier to handle in larger sizes than solid bars of the same weight. For sizes less than No. 0 this advantage does not amount to much as the bar is not very stiff. Conductors made up of small strands are probably somewhat more easily melted than solid bars of the same weight. The theory that the extra surface exposed to the air will help keep the cables cool would be correct if the heating were slow and continued, but when it is all over in less than a second the circulating air has not time to do much good.

Woven copper cable both in the round form and flat, are made expressly for lightning conductors. They have no very great advantage electrically over other forms, but they are easily handled, and lend themselves readily to making joints, where joints are necessary.

Copper Clad Steel Wire.—A wire is made for some electrical purposes consisting of a steel wire with a covering of copper. A heavy copper tube is placed over a steel bar and the two welded together, rolled and drawn out into wire. This results in a wire with a very much thicker coat of copper than would be given by plating the steel with copper. It is made with various proportions of copper and steel. The kind known as "30 per cent Conductivity" is suitable for lightning conductors, and may be used in place of the solid copper wire for the larger sizes. For sizes less than No. 4 the saving is not enough to make it worth while. Since all the current flows close to the surface of the lightning rod a No. 4 copper clad wire will carry it as easily as a No. 4 solid wire. The copper clad wire costs four-fifths as much as the solid coppei wire of the same size. It is very stiff, but this is not a serious objection, as sharp bends are always to be avoided. The principal objection to this material is the possibility oi the copper covering being injured and the steel rusted through. It is doubtful whether it would last as well underground as solid wire, but above ground it should prove as durable as the solid. It will not do for terminal rods or points. In buying copper clad wire care must be taken to distinguish it from copper plated wire which is much cheaper and not suitable for this purpose. The copper clad will be seen by cutting to have a substantial covering of copper amounting to about one-sixth of the total amount of metal in the wire.

The following companies handling copper clad wire have come to the writer's attention:

Duplex Metals Co., Chester, Pa.

J. A. Roebling's Sons, Trenton, N. J.

Western Electric Co., Chicago, Ill.

Standard Underground Cable Co., Pittsburg, Pa.

Aluminum.—Aluminum wire can be obtained from companies handling wire for electrical purposes. An aluminum rod needs to be two or three sizes larger B. & S. gage than a copper wire for the same purpose. There will be little difference in the cost, and there is little choice between the two materials. Solder can not be used on aluminum, but merely placing the wires together and wrapping well with small aluminum wire results in a very good joint. Aluminum will last as long as copper, whether underground or over head, except near salt water, where it corrodes. Aluminum may be used to advantage for terminal rods instead of copper, since the same sized wire is lighter and just as stiff and costs less. There would be little economy in using aluminum points with copper rods, unless the same company handled both kinds of wire, as the extra freight or express would probably cost more than the saving.

Galvanized Iron Wire.—This is the cheapest material that can be used for lightning rods and is fairly satisfactory while it lasts. The best grades on the market (known as E. B. B. double galvanized) should be used. It would be well to use somewhat larger sizes than are required for copper rods, say No. 2 B. W. G. for the more important lines and No. 4 for the less important. Although more heat is developed in an iron rod than in copper, the iron is much harder to melt, so in this respect it is about as safe as the copper. The objection to galvanized iron conductors is that they will not last as well as the copper. Near railroads or factories or near the sea galvanized iron wire lasts but a short time, but in the inland where the air is pure it should last from 15 to 25 years. If used for terminal rods

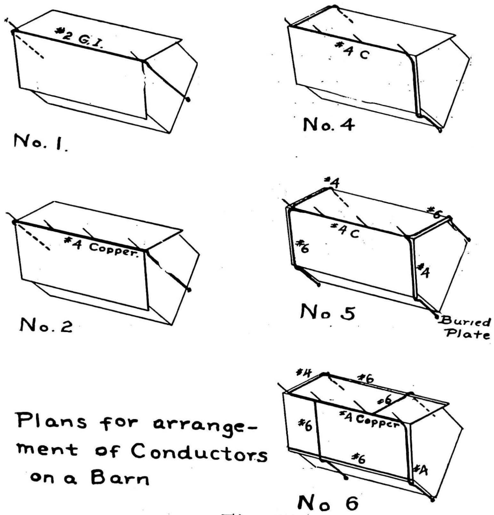


Fig. 14.

the points will rust blunt before a great while, and for this reason some other material is to be preferred. A short piece of copper wire, pointed, may be attached to the end of the galvanized iron terminal rod. The iron wire cannot be trusted underground for any length of time, hence pipe grounds would naturally be used in connection with iron rods, or else the iron wire may be joined to a copper or aluminum wire just above the surface of the ground. Joints should be made by wrapping with small copper wire and soldering.

Galvanized iron rods should be kept well painted.

Cost of Rodding a Barn.—In order to compare the different possible ways of rodding a building we shall take as an example a simple barn forty feet wide, sixty feet long, height of ridge above ground forty feet, height of eaves above ground twenty feet, distance from eaves to ridge twenty-nine feet.

The simpler arrangements outlined below will give fair protection, while the more elaborate arrangements will give greater security. For example, while plans No. 1 and No. 2 might reduce the danger from lightning to something like one-tenth part of what it would be without rods, plans Nos. 6, 7 and 8 would reduce the chance of damage to perhaps one-fiftieth part of what it was before.

Plan No. 1. Iron rod along the ridge only. Two points.

150 feet of No. 2 B. W. G. galvanized iron wire	**$1.50**
2 galvanized iron pipe ground connections	**2.40**
2 terminal rods with supports	**2.00**
Labor—placing conductor on barn	**1.50**
	$7.40

Plan No. 2. Same arrangement, but using No. 4 copper wire. One buried plate ground and one wire ground connection.

165 feet of No. 4 copper wire	$ 4.20
2 terminal rods with supports	2.00
1 buried plate ground	2.00
1 wire ground	.50
Labor—¾ day	1.50
	$10.20

Plan No. 3. Same as No. 2, but with four terminal rods......$12.20

Plan No. 4. Same as No. 3, but rods running over to the corners of the barn instead of straight down from the ridge. See illustration, Fig. 14.

This arrangement is frequently made necessary by doors in the ends of the building that interfere with running the rod down the face of the end wall. If the roof has less pitch than that given here (rise equal to one-half the span) plan No. 5 is decidedly recommended in place of No. 4. In any case No. 5 will give better protection. No. 4 exceeds the cost of No. 3 by 18 feet of No. 4 copper wire, costing 45 cents.

Plan No. 5. Rods running from the ridge to all four corners. No. 4 wire running all the way from one corner to the opposite corner. Branches to the other corners of No. 6 copper wire. Four terminal rods on ridge. One buried plate ground. Three wire grounds.

185 feet of No. 4 copper wire	$ 4.68
115 feet of No. 6 copper wire	1.82
4 terminal rods	4.00
1 copper plate ground connection	2.00
3 wire ground connections	1.50
Labor—placing conductor on building	3.00
	$17.00

Plan No. 6 same as No. 5, but a line of No. 6 copper wire run along the eaves of the roof.

120 feet of No. 6 wire	$ 1.90
Extra labor	.50
Other items as in No. 5	17.00
	$19.40

It would be well to run the lines of No. 6 wire that lead from the ridge to the ground about 15 feet back from the ends of the roof, thus providing a shorter path to ground for a lightning discharge that strikes the ridge near the middle.

This plan is advisable for a building with less pitch to the roof than the one described here. For buildings longer than 60 feet extra rods from the ground to the ridge should be placed on the side of the building.

Plan No. 7. Same as No. 6, but using two buried plate grounds at opposite corners and two wire ground connections. Estimated cost, $21.00.

Plan No. 8. Same as No. 6, but using three pipe grounds and one buried plate ground, and No. 2 and No. 4 galvanized iron conductor.

185 feet of No. 2 galvanized iron wire	$ 1.75
235 feet of No. 4 galvanized iron wire	1.65
4 terminal rods	4.00
1 buried plate ground connection	2.00
3 pipe ground connections	3.60
Labor—placing conductor on building	3.50
	$16.50

About $5.00 is saved by using iron instead of copper on a barn of this size covered with conductors as described in Plans Nos. 6, 7 and 8.

In addition to the materials named above, there would be required a half pound of No. 19 copper wire, one to three pounds of solder, some tinner's acid, some staples or screw hooks, coke or charcoal and copper plate, or galvanized iron pipe with some extra lead or solder for the ground connections.

The tools needed would be a post hole scoop or auger, gasoline torch, file or hacksaw, large pliers, sledge hammer or mallet for driving pipe, and carpenter's hammer.

Contract With Lightning Rod Companies.—As compared with the systems of rods installed by the owner, there are advantages in turning the job over to a company making a specialty of lightning rods. The completed work will very likely have a much more pleasing appearance if done by a lightning rod firm.

In the matter of safety, it would be money well invested to pay for expert advice, but it should be remembered that the real skill and knowledge is required, not for deciding what form of conductor or point to use, but in arranging the conductors on the buildings to secure the best protection with least expense, and in judging as to what depth and kind of ground connection is necessary.

The advantages of various forms of conductors have been discussed in this bulletin and there is little else to be said on this subject.

It is very difficult on the other hand to lay down rules as to the best places to run the rods and how to take care of other metal work in the house, because the conditions are different in every case. Each building is a problem by itself. It is here that trained judgment is valuable.

There are two ways a lightning rod company may furnish expert knowledge to its customers.

1. It may employ a man to devote his entire attention to this business, to visit the places of prospective customers, find all about the local conditions and lay out the plans for rodding.

The trouble with this plan is that the customer can not always tell whether the visitor is a real expert or not.

2. The company may give the agency for its rods to a local hardware dealer, tinner or plumber, requiring the local agent to send to the company complete plans and sketches of the building, showing the location of all metal work in or on the building, and notes on the character and moisture of the soil. With this information at their command, the company is in a position to give intelligent advice and can submit its plans and estimates to the customer. With any less information than this, any claim to giving expert advice is a mere pretense.

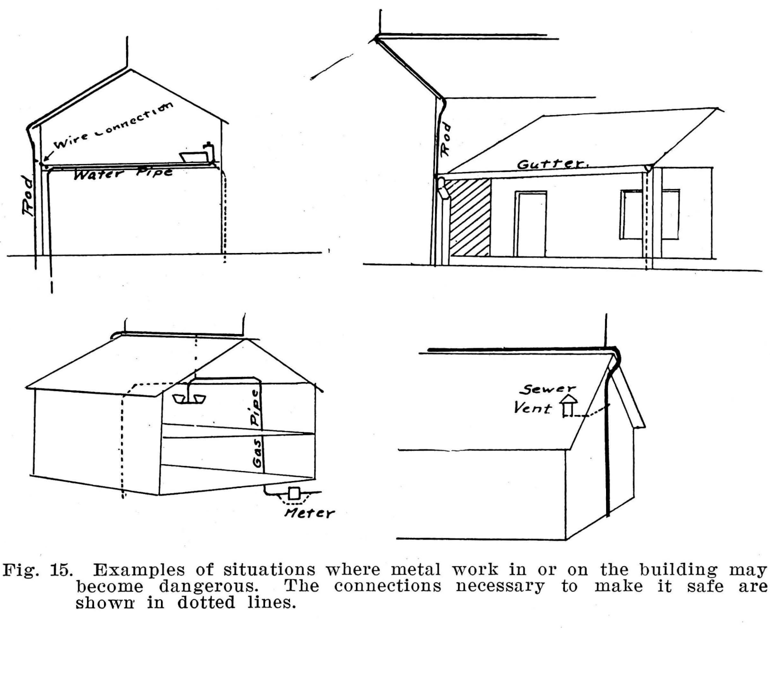


Fig. 15. Examples of situations where metal work in or on the building may become dangerous. The connections necessary to make it safe are shown in dotted lines.

Connections to Metal Work in the Building.—Large pieces of metal work about the house are likely to be a source of some danger in two ways. They may be actually struck and form part of the path that the lightning discharge uses in getting to ground, or they may be made dangerous simply by the influence of the other nearby conductors that are carrying off the discharge. This second effect is likely to occur in long conductors, such as water pipes, or rain gutters, especially when one end is near to or runs parallel with one of the rods and the other end projects away from the rod. Sparks may occur at the end of the conductor that is farthest from the rod.

It may be well to discuss briefly some of the commonest kinds of metal work about a house.

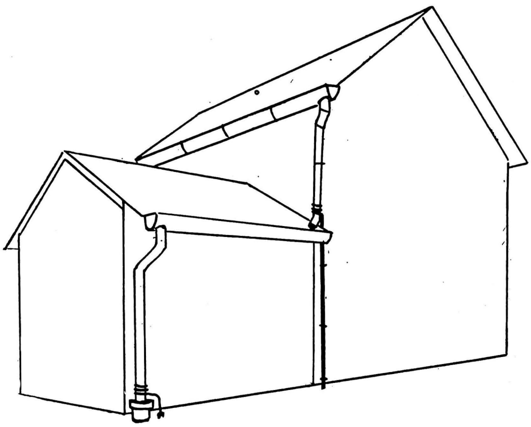
Metal on the Roof.—As has already been stated, all tin roofing, metal flashing or lining on ridges or in valleys, all ventilators, weather-vanes and ornamental iron work should be connected to conductors leading to the ground and the connection should be at the lower edge or end of each piece.

Gutters and Rain Spouts.—These are usually so located that they can be made to form a valuable part of the system of protecting

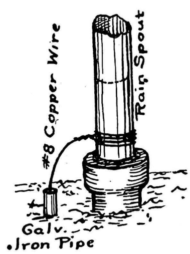
Fig. 16. Rain gutters serve to tie the different rods together, and also to protect the eaves where they are not very much exposed.

conductors, but in using them in this way three points must be kept in mind:

1. They should not be the sole protection except for less exposed points. On flat roofed buildings where the gutters run to the points that are in most danger, they should be connected to the ground by rods at the corners, placing no reliance on the rain spouts.



Case where the path offered by Rainspouts is too indirect.



Connection to Rain Spout

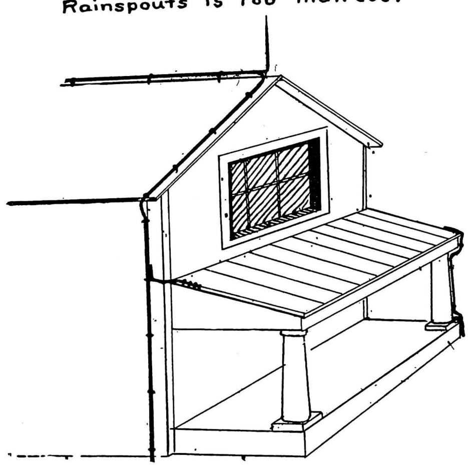


Fig. 17. If a rod passes near one corner of a tin roof, connect the two together and make a ground connection at the far corner.

The rain spouts, however, should be grounded. The gutters and rain spouts should be allowed to help out the rod in carrying off the discharge, but the rods should also be arranged so that they can help the rain spouts to carry it off. The reason for this is that the rain spouts frequently rust out before long and the joints are very poor electrically.

2. The path formed by the gutters and spouts is frequently too long and roundabout. In this case an extra connection should be made giving a more direct way for the lightning to reach the ground. See Fig. 17.

3. A good ground connection must be provided at the bottom of all rain spouts, whether they enter the earth or not. Spouts that are carried into the ground usually only reach a short way down, or else the rain water is carried off in tile pipes which are of non-conducting material.

Interior Metal Work.—Extensive piping inside the house greatly complicates the problem of lightning protection. There are two general methods of taking care of such piping:

1. Connect all ends of gas or water pipes either to the ground or to one of the lightning rods by means of stout wires. If any pipe or metal furnace flue passes within ten feet of a rod make a wire connection across between the two. At least one end of every pipe must be connected with the ground. Make ground connections to the furnace and to the kitchen stove. Figure 15 shows some of the cases where such connections are necessary. Special care must be taken of gas pipes, especially if they are of lead, keeping them well away from the rods if possible.

2. Interior piping may be rendered safe by making the system of conductors on the outside so complete that the lightning would have no tendency to make use of the conductors in the house. In order to do this, lines of conductors should be run along all hips and ridges, along all roof edges and eaves, and a vertical rod with a ground connection should be provided at each corner. At the same time the rods should all be kept at least ten feet away from any of the inside metal work

This second plan will ordinarily be easier to carry out, and is safer for any one who is not an expert.

Stoves.—Stoves, especially kitchen ranges that are in use during the summer, are objects of some danger in thunderstorms, and a connection with the ground should be made by means of a No. 10 or No. 8 copper wire. The wire may be soldered to the piece of sheet zinc or iron on which the stove rests, or attached to the stove by one of the bolts with which the legs are fastened. The wire may run directly to a pipe driven through the cellar floor or may pass through the wall to a lightning rod outside.

Electric Wiring.—Electric wires can not be connected with the ground directly, as in the case of other metal work, but grounded wires may be run **near** the electric wires so that lightning will jump across at this point instead of somewhere else.

Properly equipped telephone sets are provided with "lightning arresters" and wires running to the ground.

Electric light wires are not always provided with any special arrangement to guard against lightning. It is well to observe the following precautions: If the wires are run through the building in iron pipes, the pipes should be connected with the ground. If the main switch that controls the supply of electricity to the house is in an iron box, the box should be connected with the ground. If this switch is not provided with an iron case, a grounded wire should be attached to the meter case.

Electric light wiring and fixtures, and also telephones, should be so placed in the house that it would be impossible to stand on a hot-air register or in a bath tub, or next to a washstand or sink or radiator, and at the same time reach an electric light switch or wire. This is a precaution not only against lightning, but also against danger resulting from accidents to the wires outside.

Sewer Vents.—It is common practice to run an iron ventilating pipe from the sewer up through the roof. If the sewer is as deep as five feet below the surface of the ground, and if it is of cast iron where it goes through the cellar wall, no attention is required. If the sewer is of tile pipe where it goes through the wall, a ground connection should be made for the vent pipe.

OTHER PROTECTIVE MEASURES.

Personal Safety.—The question where is the safest place to be during a thunderstorm must be answered in a general way. Do not stand near the **end** of any line of metal conductor that may become part of the path of a lightning discharge. Do not place yourself where you may become a link in a chain of conductors that may be used by the lightning. A conductor near by will increase your danger in one position and reduce it if you are in a slightly different position. The best rule is probably to keep away from all metal work that is of any size. Especially, do not stand between electric light fixtures or wires on the one side and plumbing, radiators or hot air registers on the other side. Small metal objects are of no consequence. Stoves may be dangerous during a storm. It it just as well not to use the telephone or turn electric light switches. Do not sit or stand close to where a lightning rod runs down the outside of the building. A mental bedstead is an exception to the rule to keep away from large conductors, as the bedstead is shaped so that it very effectually protects the person in it.

The danger from open windows and doorways has probably been exaggerated, but it may be better to keep them closed unless they are covered with wire netting, in which case it makes no difference.

A person caught in a storm naturally seeks shelter from the rain, and frequently the nearest shelter is a tree. Many people have been killed by the tree's being struck, but with a little precaution there need be no more danger under a tree than elsewhere.

Do not select the tallest tree of a group.

Do not run to a single tree standing by itself, if it is possible to reach a place where there are several trees together.

Do not stand close to the trunk; keep as much as four feet away.

Do not stand where the branches are close overhead.

It is better to sit or squat than to stand. Some statistics have been gathered regarding deaths by lightning outdoors, which show that considerably more people are killed in the open than under trees; but these figures do not prove anything, because it is not known what proportion of people caught in storms take shelter under trees.

Lightning and Trees.—There is considerable difference in the liability of different trees to lightning stroke. In Belgium a record was kept for several years showing the number of trees of different kinds that were struck. Poplar suffered most, oaks next and elms third. Pine, fir and chestnut trees are also struck frequently, while the beech, birch and maple are not damaged much. The beech seems to be the safest of all, and for this reason is a good tree to plant in places where people or cattle are likely to take refuge under it in a storm. Observations of lightning strokes were carried on for a period of eight years in a German forest of 45,000 acres. Although nearly 70% of the forest consisted of beeches, there were only 21 cases of damage found. Oaks, which make up 11% of all the trees, were struck 20 times, and firs, which constituted about 6% of the forest, were struck 59 times. It does not follow that a beech tree close to a house will keep off lightning. The beech is safe only because it does not attract the lightning. The location of a tree, however, has more to do with its liability to lightning stroke than its shape or kind.

Resuscitation.—Persons sometimes receive violent electric shocks and appear to be killed, but revive after a time if their breathing is kept up artificially. If someone is struck or shocked and stops

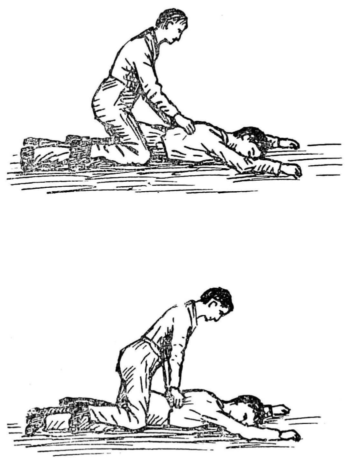


Fig. 18. Producing artificial breathing.

breathing, begin at once to force the breathing, first seeing that there is nothing tight around the neck and no obstruction in the throat. Reach in the mouth and pull the tongue forward and see that it stays so. Loosen all clothing that is tight, but do not uncover the patient unnecessarily. Place the patient flat on the floor, face down, but with the head turned to one side, and with the arms stretched out above the head, kneel with one knee each side of his thighs, place your hands on his lower ribs and press firmly down and inward, gradually throwing your own weight against him, hold the pressure for an instant and then slowly let go. Do this about once in five seconds. This should be continued for at least two hours, if necessary, or until a doctor arrives and finds that the heart has stopped beating. Cases are known of patients recovering after three hours of forced breathing. The work should not be done in a hurried or excited manner. Keep the patient warm. Let someone rub his limbs, stroking them upward, toward the heart, so as to assist the circulation. If the work takes more than a very few minutes, have your assistant apply cloths dipped in hot water and wrung out, to the chest and sides and any other part of the body that may be getting cold, but do not let anything interfere with your efforts to make the patient breathe. Stiffness or resistance to your movements is a good sign. Keep watch for any sign of natural breathing and as soon as it appears, make your movements fall in with it and help it out.

Grounding Wire Fences.—Many cattle are killed every year by standing close to wire fences during storms. Lightning strikes the wire and has no means of getting into the ground, but spreads along the wires and jumps to near by objects.

This danger can be avoided by making a ground connection with the fence every hundred feet. If the fence is long or if there are only a few cattle in the enclosure the ground connections might be put two hundred feet apart, although the protection is not quite so good with this spacing.

Drive a crow-bar four or five feet into the ground and pull it out, run a wire down the hole, making sure that it reaches bottom, give it about two turns around each strand of the fence and a few extra turns around the top wire. If the fence is of wire mesh or network, it is only necessary to make a connection at the bottom. No. 10 B. & S. copper wire is recommended for this work, but if the fence is already old and will have to be replaced in three or four years, No. 8 or No. 10 galvanized iron wire might as well be used. Using the iron wire would save three or four cents on each connection. If the fence is just being put up, fasten the ground wire to the post before it is set in the hole. If the hole is less than four feet deep the wire should be run below the bottom of the post.

Protecting Hay Stacks.—There is much loss from hay stacks set fire to by lightning. A method is suggested here for protecting hay stacks. The apparatus can be put together at odd moments and at small expense. It can be set up over the stack in a few minutes, taken down when the stack is removed, and kept for use the next year.

Get four light sticks about 1 inch by 2 inches by 6 feet, and one piece, say, 2 inches by 2 inches by 10 feet. Sharpen the ends so that they can be thrust into the stack, and drive spikes through to keep them from working further in than is intended. Get a five foot iron rod and fasten it to the end of the large stick so that it projects three feet. File the rod to a point. Fasten to it four No. 8 galvanized iron wires long enough to reach from the top of the stack to the ground. Get four ⅝-inch pointed iron bars, four feet long, and fasten these to the ends of the wires. The four lighter sticks are to

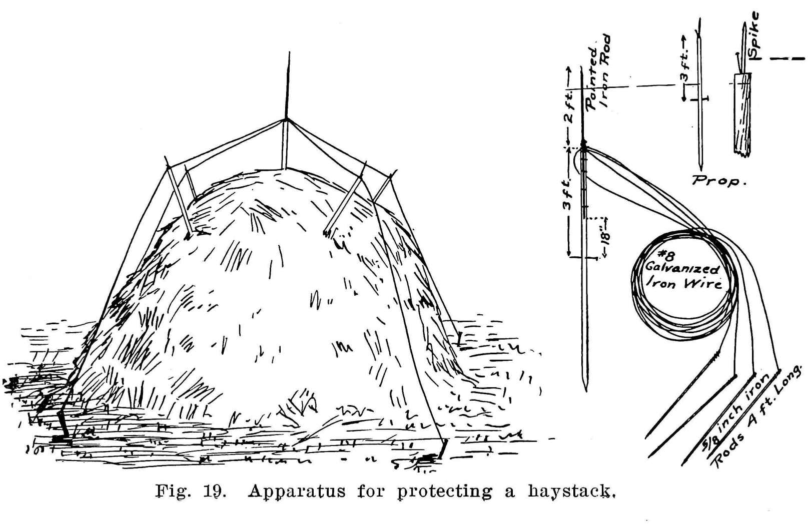


Fig. 19. Apparatus for protecting a haystack.

serve as props to keep the wires well away from the hay. Drive a large spike into the end of each, cut off the head and file it to a point. Drive in a nail next to the large spike so that the wire will wedge between them and make a good contact with the spike. The stick with the wires attached is put in the top of the stack, and the wires stretched out in four directions. Drive the iron rods into the ground. Dig a pit next to each rod and pour in a bucket of salt water. If the stack remains in the field for several weeks of dry weather pour in some more water.

Another method of protecting stacks is to set a light pole in the ground tall enough to reach eight or ten feet above the stack. Attach a rod of No. 4 copper wire to the pole pointed at the top and making a good ground connection at the bottom. Stack the hay around the pole. This will not give as good protection as the first method.

Hay Barns and Silos.—The question has been raised whether ventilators in hay barns increase the risk. Open windows or ventilators may cause greater risk if the barn is not rodded. If a rod with a point is placed directly over the ventilator, the barn is probably safer than it would be without any opening for change of air.

Wooden silos are easily protected with a rod and need the protection. If the silo is made of reinforced concrete it is doubtful whether a rod would be of much use. A lightning stroke would probably scale off and crack the concrete here and there, but not do very serious damage.

Entered at the Post Office at Columbia, Missouri, as second-class matter under Act of Congress of July 16, 1896
5,000