# Electrical Fire Hazards



The Insurance Institute of Hartford, Inc.

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# PRACTICAL INSTRUCTION

ON

# "Electrical Fire Hazards"

By

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of the

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# Electrical Fire Hazards

## Part No. 1.

### INTRODUCTION.

Electricity in motion, lights lamps, drives motors, refines metals, raises to a high temperature all sorts of electrical heating devices, energizes the telephone, telegraph and electric bell. From one outlet we may supply an incandescent lamp, a flat-iron, a coffee percolator, a toaster, an electric fan, a heating radiator, a sewing machine motor, a broiler, a hot-water heater and a number of other devices. Thus, we may from one simple fixture use electricity in motion for light, heat or power. Electricity at rest, has few effects of practical value. So we are to study electricity only as it moves, that is, flows and does work.

### WHAT IS ELECTRICITY?

Electricity has been described as juice. Since Benjamin Franklin brought it from the sky with a kite, no better, or more scientific definition has been made. In a word, we cannot tell you what electricity is. Our interests, as Fire Prevention Engineers, are concerned only in the event of imperfect installations and the use of improper devices and materials which would constitute a fire hazard and the National Electrical Code, the recognized standard of electrical installations in this country and in Canada, is confined to such questions as will provide proper methods and materials that such hazard may be minimized. We might say that the National Electrical Code was for the purpose of using electricity in the capacity of a servant. Used as such, it is safe. When, however, it is permitted to become a master, it not alone becomes a hazard, but a menace, as well.

### HISTORY.

Electricity is not an invention. Like steam, it is a discovery. Its discovery was not much, when viewed in the light of the world at its birth, some 600 B. C.; merely a piece of amber rubbed against the clothing of the Greek Thales; merely the gaining of a strange property of first attracting and then repelling light objects brought near it. Dr. Gilbert, a physician to Queen Elizabeth, may be considered as the founder of the science, as he appears to have been the first philosopher who repeated the observations of the ancients. The experiments of Sir Isaac Newton, before the Royal Society, in 1676, excited surprise and comment. Sir William Watson succeeded in firing gunpowder by the electric spark and established the theory of positive and negative electricity.

A high place in the history of electricity must be allotted to the name of Benjamin Franklin. His researches did much to extend our theoretical and practical knowledge of electricity. In 1827, Dr. G. S. Ohm rendered a great service to the science of electricity by publishing his mathematical theory of the galvanic current. In 1831, Faraday began with the discovery of the induction of electric currents, that brilliant series of experimental researches which has rendered his name immortal.

To attempt to trace the history of the dynamo-electric machine would more than fully occupy the time generally assigned to a single lecture. Suffice it to say, that the first machine of this type was invented by Faraday, who modestly described it merely as "A New Electrical Machine."

Later came the successful solution of the divisibility of the electric light by the invention of the incandescent lamp.

The invention of the dynamo rendered the extended commercial application possible of another invention, the electric motor, which has been successfully developed and placed into actual use to an extent that appears almost incredible. It has been recently stated by the Society of Electrical Development, that electricity is being used in over 5,000 different ways.

## PURPOSE OF ELECTRICAL INSPECTION.

A fire prevention engineer, or an electrical inspector, should not endeavor to ascertain if the installation will meet the demands of its intended uses. The function of inspection is single, not manifold. The one purpose should be to examine the installation, whether it be for electric light, heat or power, that weak points, if any, which might cause a fire or be dangerous to life, may be pointed out and corrected. I do not think it would be wise for the fire prevention engineer, or electrical inspector, to engage in the engineering problems of the installation he may inspect, but he should be capable of passing on plans and the execution of the work that life and property may be safely guarded.

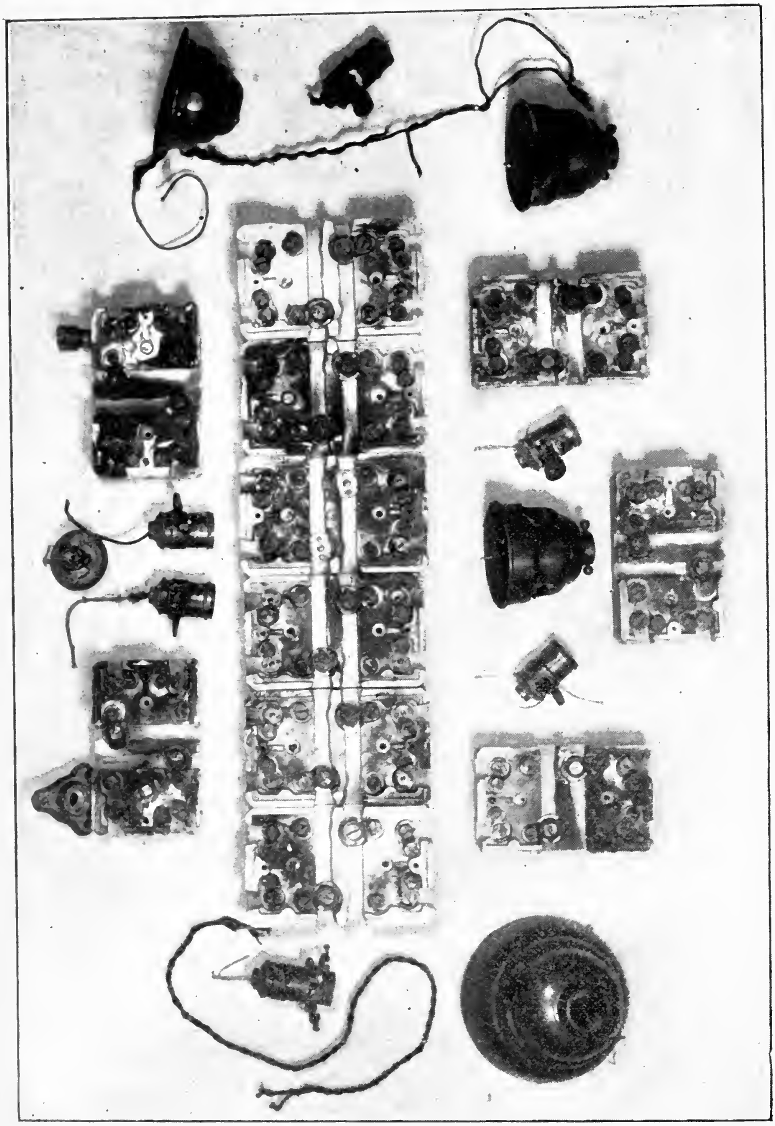
The wisdom in refraining from engaging in the electrical engineering problems of the installation, may be seen in the several methods for determining the size of conductors to be used for alternating current motors, there being different considerations for the varying types of motors, the uses, the power factor, the voltage and the starting and running loads of the motors being different in the several types and localities. The method, protection and execution of the installation is what should concern the fire prevention engineer, or electrical inspector.

**IRES CAUSED BY LECTRICITY.**

Among the problems, subsidiary to the question of installation, is the relation of electricity to the fire hazard. Virtually all the precautions for the maintenance of conditions of safety may be found in the provisions for adequate conductivity and efficient insulation, as fires by electricity are only caused by one or both of two general ways.

**Y OVERHEATING.**

FIRST:—By the overheating of conductors, wires, switches and other devices which may result in a fire to surrounding inflammable material and objects. Overheated wires will ignite the insulation and the flame will travel along the conductor, igniting other inflammable objects in its path. That this overheating may be avoided, we should examine very closely the types and sizes of fuses used. The old fashioned link fuses should never be permitted unless enclosed in cabinets of proper construction, except on switchboards located in rooms of fire resisting construction. The so-called fuse wire should not be permitted, under any circumstances, because of the absence of the copper terminals. Fuses of any type should never be installed in locations where there are flyings of ignitable material, dust or gases, as, even with enclosed fuses, the gases formed by the fusing metal, in the fuse, do tear apart the fuse casing and the arc, also the



Courtesy of Commissioner James E. Cole, Wire Dept., Boston, Mass.

Group of cut-outs, parts of fixtures and sockets burned out. These cut-outs were for the old fashioned link fuses and had mica covers which made them extremely hazardous, because when the link fuses operated the mica cover was broken and thus permitted the molten fuse metal to be expelled from the cut-out. The use of this type of cut-out has not been permitted for a number of years.

molten metal will ignite combustible material and cause fire.

All conductors are heated by any current however small, but if the conductor is overloaded, and over-fused, it may become hot enough to ignite the insulation. Hence it is important that wires should be of sufficient capacity to carry the load, and all conducting parts of electrical appliances must be properly proportioned. Overheating of conductors and devices is thus one of the ways in which electricity may cause a fire.

Assuming, for purposes of illustration, that the conductors of a circuit were properly proportioned and were properly protected by fuses when they were installed. Without consideration of possibilities the number of lamps is increased or a larger motor replaces the original motor. When this increased load is thrown upon the conductors, the fuses "blow" and open the circuit, just what they were designed to do. Someone increases the size of the fuse, or worse yet, substitutes a copper wire, a hair pin, strips of iron, brass or lead, and I have even found ten cent pieces in the cut-outs. The lights burn brightly, or the motor runs satisfactorily. Later, however, the wires overheat and the insulation is ignited, thus setting fire to the surrounding objects.

It is important that we become familiar with the safe fusing of wires, as the capacity of standard fuses are plainly marked on the outside. The smallest wire permitted in any circuit, and the one most generally used on lighting circuits, is No. 14, B. & S. gage and this size wire should never be fused with a fuse larger than 15 amperes, for a motor circuit, nor with a fuse larger than 10 amperes, for a lighting circuit.

As another example which may cause the wires to heat, is that of a poor joint or splice in a wire. When a small amount of current flows the heat is not appreciable, but as the current increases, owing to the poor contact, the joint heats and the insulation is ignited. All splices should be well made and should be mechanically and electrically secure before soldering, that the opportunity for heating at the splice, will be removed. Again, we may have this overheating by poor connections. A binding screw is set up securely, but, owing to the vibration of the building this contact becomes loose, heating takes place and the insulation on the wire is ignited because of the heating conductor.

A few examples of the foregoing, the result of actual field experience, may be of service at this time.

One fire was due to lights being added to old wiring until some of the branch circuits were overloaded. This overload and poor workmanship resulted in a fire causing a loss of $190.00.

A short-circuit occurred in a flexible cord pendant destroying the cord and burning itself out at the ceiling rosette. An investigation developed the fact that blown fuses on the circuit were bridged with pennies.

Heating at a loose contact on a resistance used in starting a 100 horsepower motor, and rubber-covered wire in close proximity to the contact, offered conditions which started a fire in a packing plant with a resultant loss of $200.00.

An amateur extension of wiring from a standard equipment resulted in a short-circuit on an overfused circuit and a loss of $7,500.00.

A fire originated from a short-circuit above a metal ceiling and spread through the open partition into the attic above. The original electrical installation was good, but trouble was caused by overloading the circuits. The wiring, as originally installed, was for 16-candle power lamps only, but these were afterwards replaced by 150-candle power lamps without increasing the size of the wire in the circuits. The branch circuits, which under the Rules should not be fused above 10 amperes, were fused for thirty amperes and the main fuse block was bridged with strips of lead. Naturally the fuses failed to operate and the fire caused damage to the extent of $8,000.00.

## BY THE FORMATION OF AN ARC.

SECOND:—Fires are caused by the forming of an "arc". An arc is always accompanied by heat, and if it is of sufficient capacity may not only ignite combustible material, but may melt metals, also. Arcs may be formed between the two wires of a circuit when the wires are too close to each other. An arc may also be formed between one wire of a circuit and any grounded metal, or, between an ungrounded metal and another grounded metal, the former being in contact with a wire of a circuit. A wooden truss may be reinforced with a long metal rod, which rod may be in contact with one wire of a circuit and a grounded gas pipe, where, if a sufficient amount of current was flowing, an arc would be established, a hole melted in the pipe and the escaping gas ignited by the arc. Perhaps a short-cut definition of the word "Arc" may assist in remembering what I have said: "An arc is the physical evidence that current is flowing." Permit me to again draw from field experience by way of illustrating how fires may be started by an "Arc".

As an example of an arc between wires, I might cite what may happen behind the canopy of a fixture where the wires of the fixture are joined to the circuit wires. The wireman, through carelessness may fail to properly tape or cover the joints, and as some canopies have very little space in the rear when the canopy is pushed back, the wires come in contact. When the current is turned on, an arc is established between the conductors which, before the fuses may open may set fire to the insulation and thus to the building.

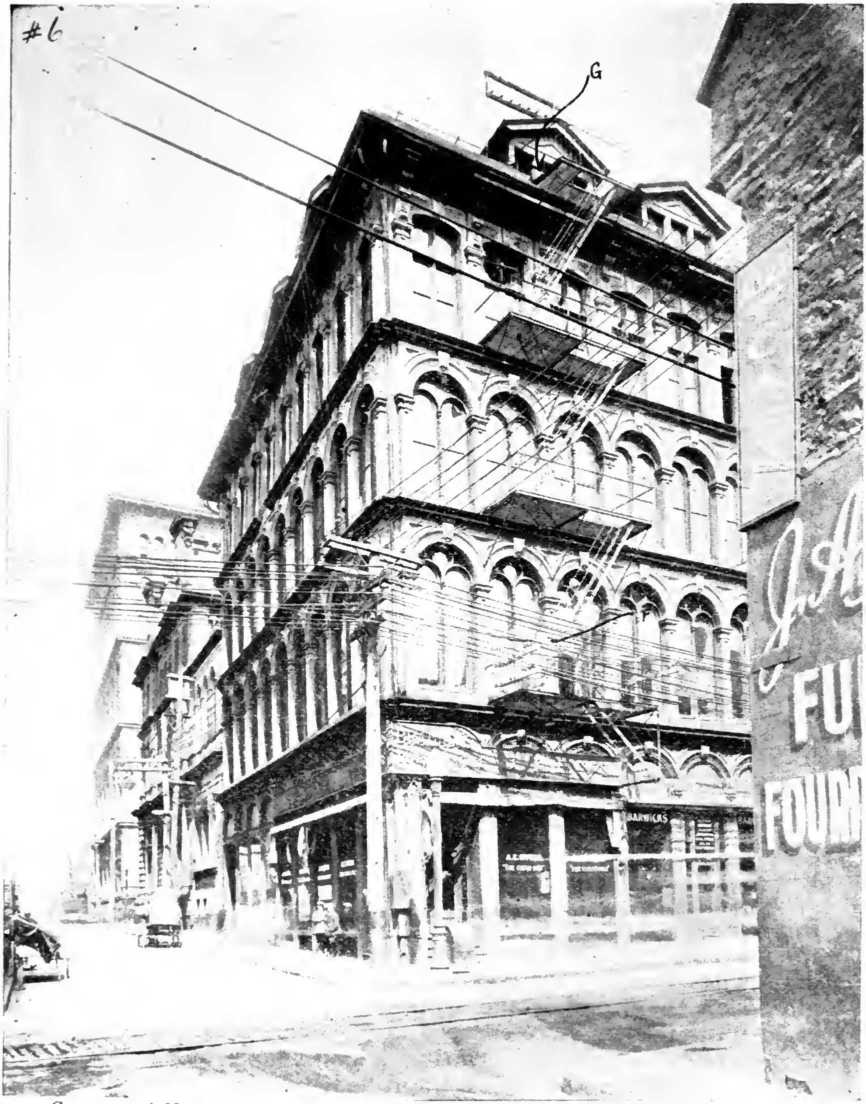
As an example of an arc between one circuit wire and grounded metal, I might state an experience where one of the circuit wires became grounded on the gas pipe at the fixture outlet, thus establishing an arc, setting fire to shavings which accumulated when the house was built. The loss was $25.00

A short-circuit due to defective insulation in a combination fixture created an arc of sufficient intensity to puncture the gas pipe below the joint and ignite the gas, with a fire loss of $50.00.

A metal ceiling was put in place over porcelain cleat work in a basement kitchen without the knowledge of the inspection department having jurisdiction. The insulation of the wire broke down because of dampness and became grounded on the metal ceiling. The arcing ignited the insulation on the wire and the fire was communicated to woodwork, doing considerable damage.

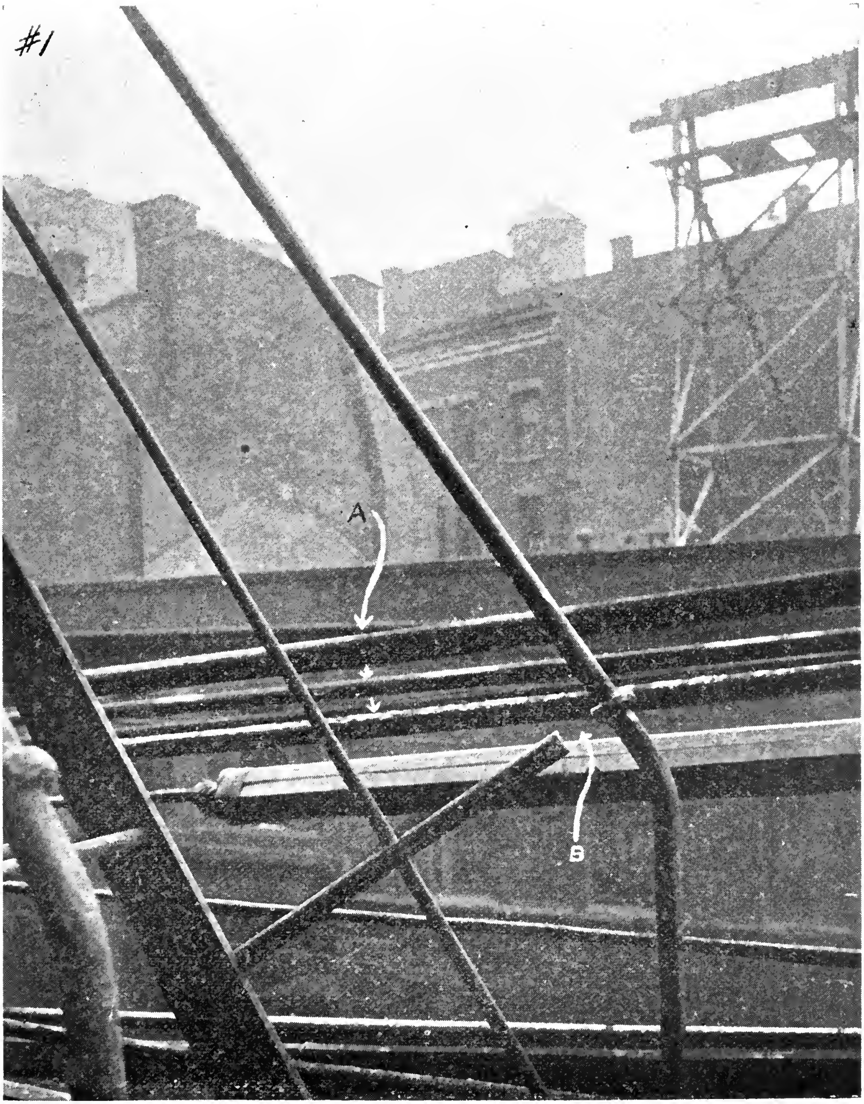
As a somewhat different example of an arc the following is most interesting.

The property consisted of a group of buildings, some of which were used as stores, some for light manufacturing, the principal occupancy being a hotel. On the front of the hotel is a fire escape which acted as an electric conductor. Among the wires in front of the building are some street railway feeders. These feeders were erected before the fire escape was placed on the building and with the putting in place of the escape, the feeders were encased in wooden sleeves where too close to the iron work. During a noon hour one of these 250,000 circular mill feeders, unprotected because of damage to the wooden sleeve, came in contact with a handrail support, and an arc was formed which lasted until the cable fused and fell apart, also fusing the handrail. The fire escape extends from the first to the fifth floors with a platform at each floor. Its supports are secured in the stone wall except at the top where the rods extend through a wooden cornice, the wall




Courtesy of National Fire Protection Association.

Shows points of contact (F) between electric wires and fire escape, and fused rod (G).

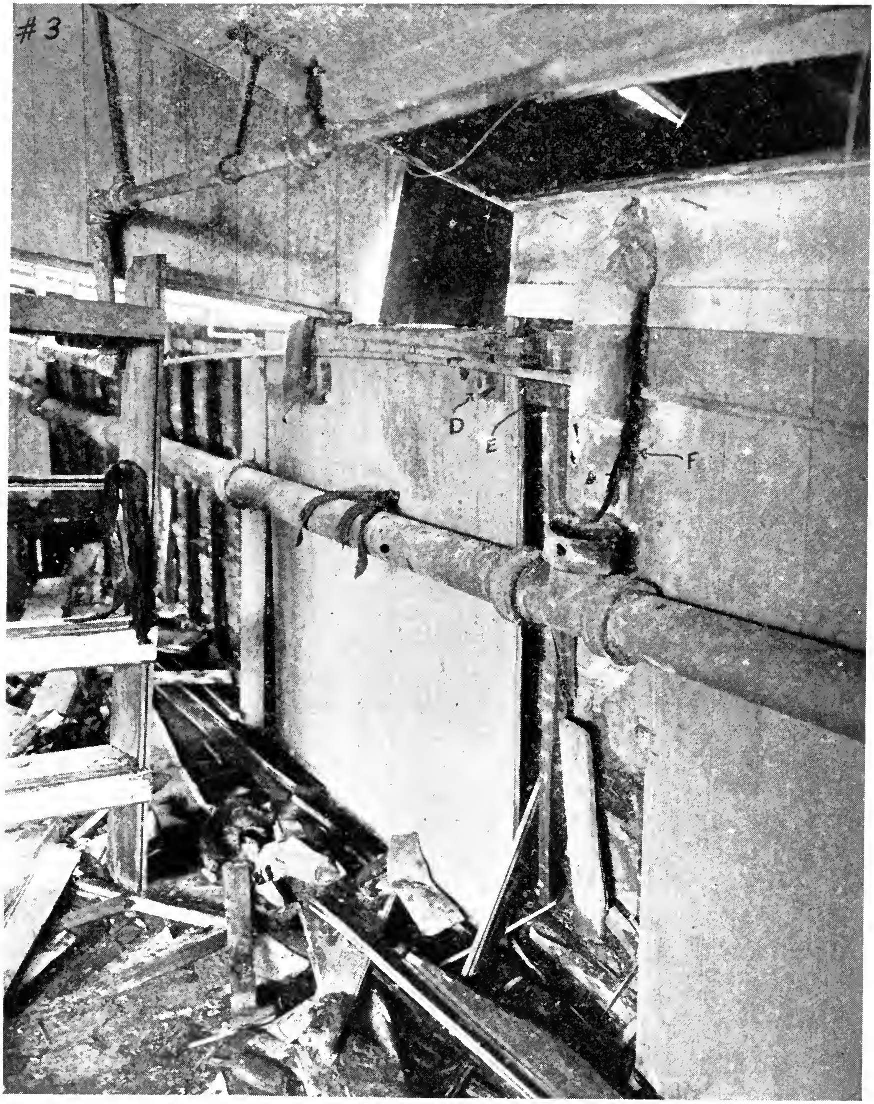



Courtesy of National Fire Protection Association.

Fire Escape at second floor. Shows trolley feeders (A) point of contact with fire escape and fused rod (B).

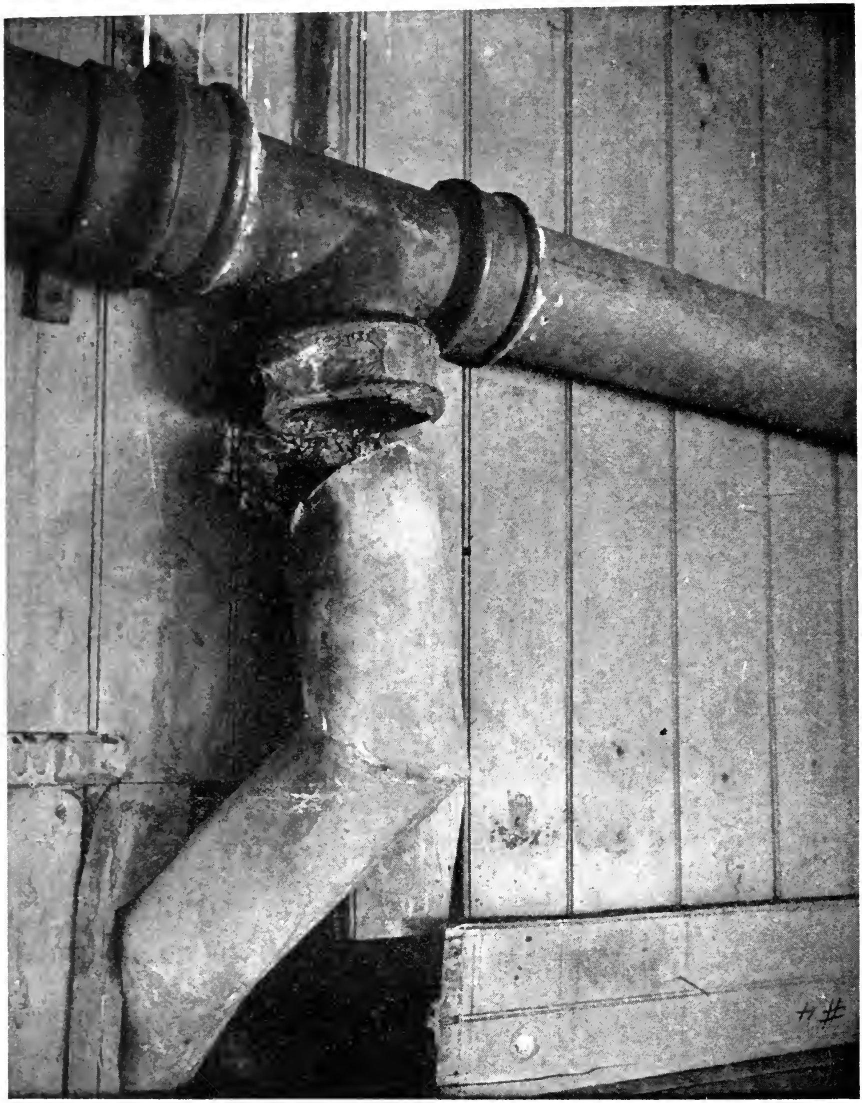

Courtesy of National Fire Protection Association.

Fire escape and cornice, fifth floor, showing fused iron rod.




Courtesy of National Fire Protection Association.

Fifth floor interior. Shows nut and plate (D) at end of fused rod, unused gas pipe (E), roof drain (F).



Courtesy of National Fire Protection Association.

One of the several sewer pipes damaged or fused by heat generated by resistance caused by poor conductivity of leaded joints. Note the charred sheathing.


Courtesy of National Fire Protection Association.

One of the cases where electric current jumped from sewer pipes to adjoining water pipes, fusing both of them.

and then into wooden sheathing where the rod is held by an iron plate and nut. The plate and nut were in contact with an unused gas pipe and this in turn was in contact with the roof drain. The current from the feeder passing to the fire escape, traveled up the iron work to the fifth floor melting the metal at several points where the contact was poor. At the fifth floor the current passed into the building over the supporting rod, and thence to the nut, plate, gas pipe and sewer piping. The supporting rod was fused on the outside of the building at the fifth floor. The heat caused by the current through the resistance of the leaded joints of the sewer pipes ignited adjacent wood sheathing. Small fires were started in different parts of the fifth floor where sewer and water pipes were located, the leaded joints of cast iron sewer pipes being melted. In several places where the water pipes were in contact with sewer pipes, arcs were formed which melted both.

As an example of an arc between a metal pipe and another metal pipe, the latter being grounded, an experience in a house, in the Back Bay District, Boston, some years ago, is of interest. The house where the fire started did not have any electric light wires in it. In the basement, a gas pipe rested on a water pipe, making a slight contact. Either in the ground or in an adjacent building, a wire was in contact with a gas pipe. Probably due to the resistance of the joints, the water pipe was a better ground than the gas mains. An "arc" was established between the gas and the water pipe, which melted a hole in the gas pipe, set the gas on fire, and ignited the woodwork in the basement ceiling.

## REQUISITES FOR A SAFE INSTALLATION.

That the installation may be safe, attention should be given to the excellence of material, simplicity in design which will permit of easy inspection, and repairs of all wiring and appliances. Special attention should be paid to the mechanical execution of the work, careful connecting, soldering, taping of conductors, securing and attaching of fixtures and the use of "approved fittings."

## ELECTRICAL TERMS—THEIR MEANING.

Electric power may be transmitted by either direct or alternating current.

DIRECT CURRENT:—By the term "Direct Current" we understand it to refer to an undirectional current. As ordinarily used, the term designates a practically non-pulsating current. It is of such character that what is usually called the "direction" of the current is always the same, or, more exactly, the magnetic effects of the current are not being reversed.

ALTERNATING CURRENT:—An alternating current is one that reverses in direction at regular intervals. Such reversals of current direction are made automatically by an alternating-current generator. The number of changes in a second of time is called the frequency, or cycles, 25 to 60 being the commonest now in commercial use.

Both direct and alternating-current systems are in use for light and power, but the alternating-current has replaced many of the direct-current systems, except in most Street Railways and in isolated plants. Where power must be transmitted to a considerable distance, alternating-current is used because of economic reasons. Incandescent lamps, heating and other current consuming devices are interchangeable on the two systems. Motor and arc lamps, however, require different designs for the two systems. The same amount of current will heat a conductor to the same degree of temperature, whether it is a direct or alternating-current system. As a whole, no distinction may be made as regards the fire hazard between the two systems, except that a direct current arc is more severe than an alternating current arc. The same degree of care in workmanship, selection of materials, insulations, fuses and other protective devices should be made for both systems.

CURRENT:—The practical unit of electric current is called AMPERE. The flow of water in a pipe is measured by the quantity of water that flows through in a second, as 1 gal. per sec., 8 gals. per sec., etc. Similarly the flow of electricity in a circuit is measured by the amount of electricity that flows along it in a second. More current will, all conditions being equal, do more work, and will always cause more heat in the conductors and appliances. Furthermore, the heating effect in conductors such as, metals, varies with "the square of the current", i. e., if one unit of current produces a certain amount of heat in a wire, twice as much current will cause four times as much heat in the same wire, three times the current will cause nine times the heat and so on. The instrument for measuring current is called an ammeter.

VOLTAGE:—The electrical unit of "PRESSURE" is the "VOLT". A volt means the same thing in speaking of a current of electricity that a pound pressure does in speaking of a current of water. Just as a higher pressure is required to force the same current of water through a small pipe than through a large pipe, so a higher electrical pressure is required to force the same current of electricity through a small wire than through a large wire. Since it is the voltage which may cause electricity to pass from its proper path and seek other and perhaps dangerous paths, higher voltages require better insulation on wires and in appliances. The voltage used thus becomes an important factor in determining the protection for safety.

DIFFERENCE IN POTENTIAL:—The voltage (pressure) between two points in an electric circuit, which points may be between the conductors of a circuit, or between one conductor of a circuit and a path to earth, is sometimes spoken of as the "difference in potential", or the "drop in potential" or merely the "drop", between those two points.

Where such a condition or difference exists, current may pass between them. We have said that "current passing along a conductor produces heat" and when it jumps between the conductors or between a conductor and a path to earth it produces an "arc".

RESISTANCE:—Resistance is the physical property of a material by virtue of which it opposes the flow of an electric current. The Ohm is the practical unit of resistance. All substances offer resistance to the passage of current. A good conductor offers little resistance, while a poor conductor may offer considerable resistance and then be a good insulator. Copper is one of the best conductors because of its low resistance. Iron is about one-sixth as good a conductor as copper, and thus the same size and length of iron wire would have about six times the resistance of the same size of copper. Wood, when dry, is a poor conductor, but a good insulator.

OHM'S LAW:—Ohm's Law is a method of expressing relationship existing between the electromotive force, current and resistance, and is practically the basis of most electrical computations. It is expressed in various forms, as follows:

$$\text{Current Flow} = \frac{\text{Electromotive Force}}{\text{Resistance}} \text{ or, } C = \frac{E}{R}$$

Electromotive force equals the current flow multiplied by resistance.

Electromotive force = Current Flow x Resistance, or E = C x R

Resistance equals the electromotive force divided by the current flow.

$$\text{Resistance} = \frac{\text{Electromotive Force}}{\text{Current Flow}} \text{ or, } R = \frac{E}{C}$$

C = Amperes. E = Volts. R = Ohms.

Electromotive force varies directly as the current and resistance.

Resistance varies directly with the electromotive force and inversely as the current.

Current varies directly with the electromotive force and inversely as the resistance.

In this form, "Ohm's Law" applies only to direct-current circuits or non-inductive alternating-current circuits, the latter, however, with some modifications.

POWER:—The term "watt" is merely a unit of power and denotes the power used when one volt causes one ampere of current to flow. The "watts" consumed when any given current flows under any pressure can always be found by multiplying the current in amperes by the pressure in volts. Thus, if an incandescent lamp takes 0.5 amperes when burning on a 110-volt line, the power consumed equals 0.5 x 110 = 55 watts. That is, power = current x pressure, or watts = amperes x volts. Thus if the current in an incandescent lamp is ½ ampere and the voltage across the lamp terminals is 110 volts, the power is 55 watts. With alternating current, the product of the volts and amperes does not give the power consumed, there being another factor known as the power factor. With direct current, if the current, as read by a current meter, known as an ammeter, is 100 and the volts are 100 then the watts are 10,000 or 10 kilowatts. With alternating current, this power factor may be as low as .60, so that the power instead of being 10,000 watts, may be only 6,000 or 6 kilowatts. A horse-power equals 746 watts, so that a kilowatt equals 1-⅓ H. P. and is expressed as 1 K. W.

MULTIPLE CONNECTION:—In this system the pressure or voltage is constant, being that required for a single unit. The total quantity of current, however, or the amperes will vary directly as the number of units to be supplied. When devices are so connected that the current has a path through each separately from one circuit wire to another, they are connected in "multiple" or in "parallel."

SERIES CONNECTION:—In this system the same current traverses in succession, or in tandem, all the translating devices. The electrical pressure or voltage will vary directly as the number in circuit, the current, amperes, remaining unchanged, whether one or the whole number is being supplied.

CUT-OUT:—A cut-out is automatic in its action and may be a fuse or a circuit-breaker. A fuse is an element designed to melt or dissipate at a predetermined current value, and intended to protect against abnormal conditions of current. A circuit-breaker is a device designed to open a current carrying circuit without injury to itself. Both in operation correspond to the safety-valve on a steam boiler.

GROUND:—A ground may be either an intentional or an accidental connection between a part of an electric circuit and the earth, or any metal or connecting substance which are in electrical connection with the earth, such as water or gas pipes, metal work of buildings, etc.

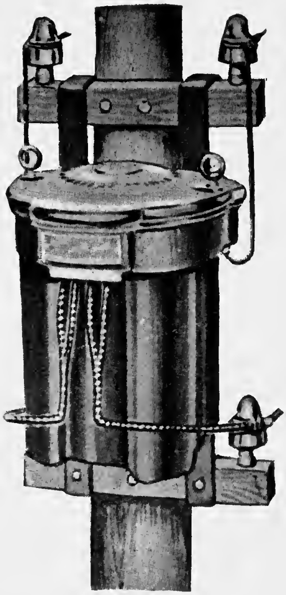
SHORT-CIRCUIT:—This is a condition which shortens the path below the normal over which the current is supposed to flow when performing its designated functions. Such a condition is frequently the result of accident or the failure of some insulation, and since it usually allows excessive currents to flow, a short-circuit may be dangerous and liable to cause a fire through the heating of the conductor, thus igniting its insulation, or a poor contact which may cause arcing and burning at the junction of the conductor.

CONSTANT-POTENTIAL SYSTEM:—A constant-potential system is one in which the pressure, or voltage, between the circuit wires is approximately the same at all points. With such a system, as the load on the circuit increases, the current increases.

CONSTANT-CURRENT SYSTEM:—A constant-current system is one in which the current (amperes) is maintained approximately constant, regardless of the number and character of the power consuming devices on the circuit. The arc and incandescent lamps are usually operated on a constant-current system, principally for convenience of control and low cost of installation.

TWO-WIRE SYSTEM:—A two-wire system is a metallic circuit formed by two paralleling conductors insulated from each other.

THREE-WIRE SYSTEM:—A three-wire system is a double multiple, the two outside wires are considered only when the wire is being figured, as when the system is under full load the neutral wire does not carry any current. The three-wire system has for its chief purpose the lessening of the cost of the conductors, in that three wires may be used instead of four, and bears no relation to the fire hazard.



Courtesy of The Insurance Field.

An oil insulated transformer. One of the hazards in a transformer, is the heating of the coils due to the flowing of electrical energy. To aid in reducing this hazard the coils are immersed in oil for insulating purposes, which oil will ignite at a reasonably high temperature. In transformers of the larger capacity the oil is cooled by water circulating in a separate compartment.

TRANSFORMERS:—A transformer is a stationary induction apparatus which changes electric energy to electric energy, through the medium of magnetic energy without mechanical motion. By the means of alternating current, electric power may be transmitted from the generating station to the point where the power is to be utilized, and then transformed with small loss to a voltage better suited to motors and lamps. In some of the hydro-electric stations, the alternating current is generated at 2300 volts, and in some instances 6600 volts, which voltage is "stepped-up", through transformers, to 66,000, and even to 250,000 volts and is transmitted at the higher voltage to the place where it is to be used, where it is "stepped down", sometimes to several voltages, through transformers, to a safe, usable voltage. It is far more economical to transmit power at high voltage and the usable current in many of our communities is generated, by water power, many miles away from its application.

## Part No. 2.

### REQUIREMENTS.

In judging of installations, it must be kept constantly in mind that conditions will not improve after the wiring and appliances have been in use for some time. Requirements are, therefore, made to anticipate in part such deterioration which may be surprisingly rapid when inferior materials are put in by careless workmen, used and abused by those having little or no understanding of electrical affairs and no appreciation of the hazard.

The hazards of electricity were early recognized, and, on October 19, 1881, the New York Board of Fire Underwriters issued a resolution in the following form:—

"RESOLVED: That the Committee on Police and Origin of Fires are hereby directed to notify the owners and occupants of all buildings in which uncovered electric light wires, or in which arc lights with open bottoms or without globes are found, that the wires must be covered, and the lamps altered to conform to the rules of the Board within ten days from date of notice, and request that the lights shall not be used until the alterations are made; and in case the alterations are not made within said time, the Committee are hereby directed to notify the members of the Board of such failure and the companies insuring said property are hereby recommended to give notice to the owners and occupants of such buildings that unless the request is complied with, and the alterations made within a reasonable time, that the insurance on said property will be canceled."

Later, in January, 1882, the same Board issued simple rules on the same subject. These rules were not alone elementary, but indefinite, as well. A reference to them, at this time, will assist in showing the progress made since that issue of rules.

> "Wires to be thoroughly and doubly coated with some approved material."
> "All wires to be securely fastened by some approved non-conducting material."
> "When it becomes necessary to carry wires through partitions and floors, they must be secured against contact with metal or other conducting substances in a manner approved by the Inspector of the Board."
> "The conducting frame work of chandeliers must be insulated and covered the same as wires."

In May, 1882, the National Board of Fire Underwriters issued its first set of rules, which were later adopted by the Boston Board of Fire Underwriters. The first rules of the New England Exchange were issued in August, 1885. From this date to the early part of 1892, rules were issued by various rating organizations and, consequently, different considerably. Through the initiative of Mr. C. M. Goddard, Secretary of the New England Insurance Exchange, rules were prepared, in 1892, by the Underwriting Boards in New England, Middle, South Atlantic and Gulf States. From this grew the Electrical Committee of the Underwriters' National Electrical Association, and later in 1911 the Electrical Committee of the National Fire Protection Association.

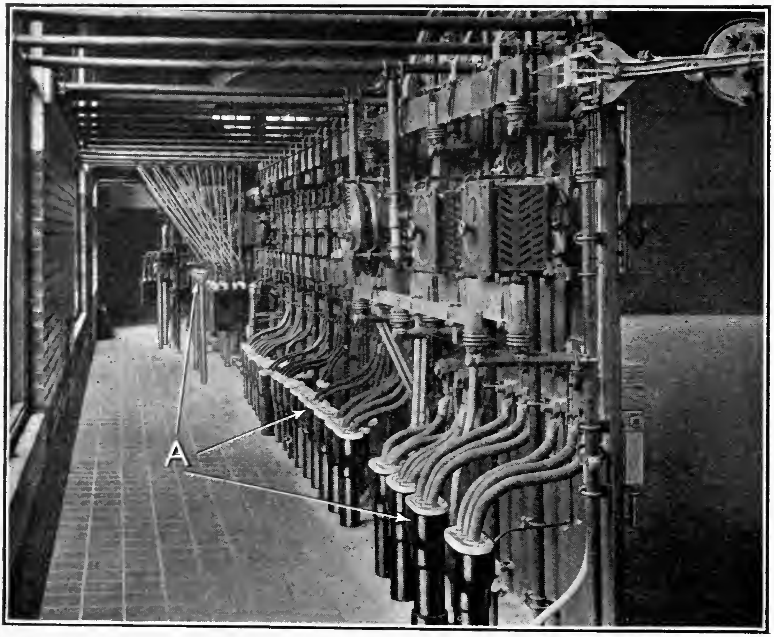
While most of the members of the old Electrical Committee are now members of the Electrical Committee of the National Fire Protection Association, the membership of that committee has been enlarged, so that it now includes representatives from the American Institute of Electrical Engineers, the American Electric Railway Association, The National Electrical Contractors' Association, the National Association, the National Association of Electrical Jobbers, the National Association of Electrical Inspectors, the National Electric Light Association, the Chief Electrical Inspector of the City of Chicago, also the Electrical Engineer of the City of New York. To these have since been added the Electrical

Engineer of the United States Bureau of Standards. Our standard now enjoys the endorsement of the Federal Government. So you will recognize that all Associations in any way interested in the varied forms of the application of electricity, that it may not prove a menace to life, limb and property, have a voice in the making of the National Electrical Code.

## GENERATING AND SUB-STATIONS.

The modern electric generating and transformer station is usually constructed of brick or concrete walls, with concrete floors, concrete roof and partitions of fire resisting material, so that the amount of combustible material is small.

The practice has been, for some time, to erect large stations from which the current is transmitted at a high voltage to a number of sub-stations, where the usable voltage is ob-

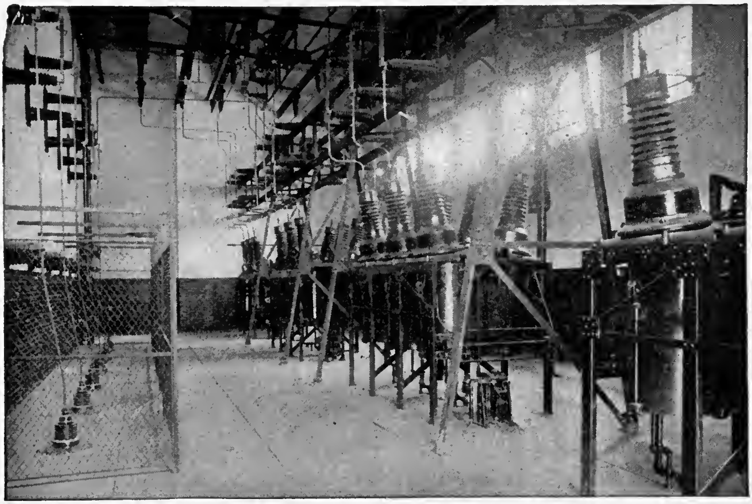



Courtesy of Crouse-Hinds Company.

Rear of switchboard in a fire proof generating station. In addition to the wide, clear space between the wall and the rear of the switchboard, attention is called to terminal fittings marked (A) on the ends of the conduit. These terminal fittings, it will be seen, give a separately insulated hole for each conductor.

tained through transformers. For example, some of the current used by the Hartford Electric Light Company is generated at the Falls Village, Conn., hydro-electric station and transmitted at 66,000 volts, which is stepped down to 11,000 volts at sub-stations in Torrington, Bristol, Thomaston, New Britain and Hartford. From the station at Hartford, the current is again transmitted to a number of sub-stations and again transformed to 2300 volts. From these sub-stations, the current is now sent out to Windsor, on the North; Manchester, on the east; Rocky Hill and Easthampton, on the south and Unionville and the Granbys on the west. Transformers are located generally on the poles in the several communities served in which the current suitable for use in lamps, motors and other appliances, generally 110-220 volts is obtained through being transformed from the higher to the lower voltage.

As another example, reference may be made to the New England Power Company, which has five hydro-electric stations on the Deerfield River in Western Massachusetts, and



**Courtesy of Turners Falls Power & Electric Company.**

66,000 volt, remote control, oil switches in the sub-station of the Turners Falls Power and Electric Company at Amherst, Mass. From this sub-station the distribution of high-potential current to a number of places in the Connecticut Valley is controlled. When disconnecting the conductors of a high-potential circuit an "arc" of considerable proportions is created, to prevent which the switches are opened in oil, hence the term, "Oil Switches".

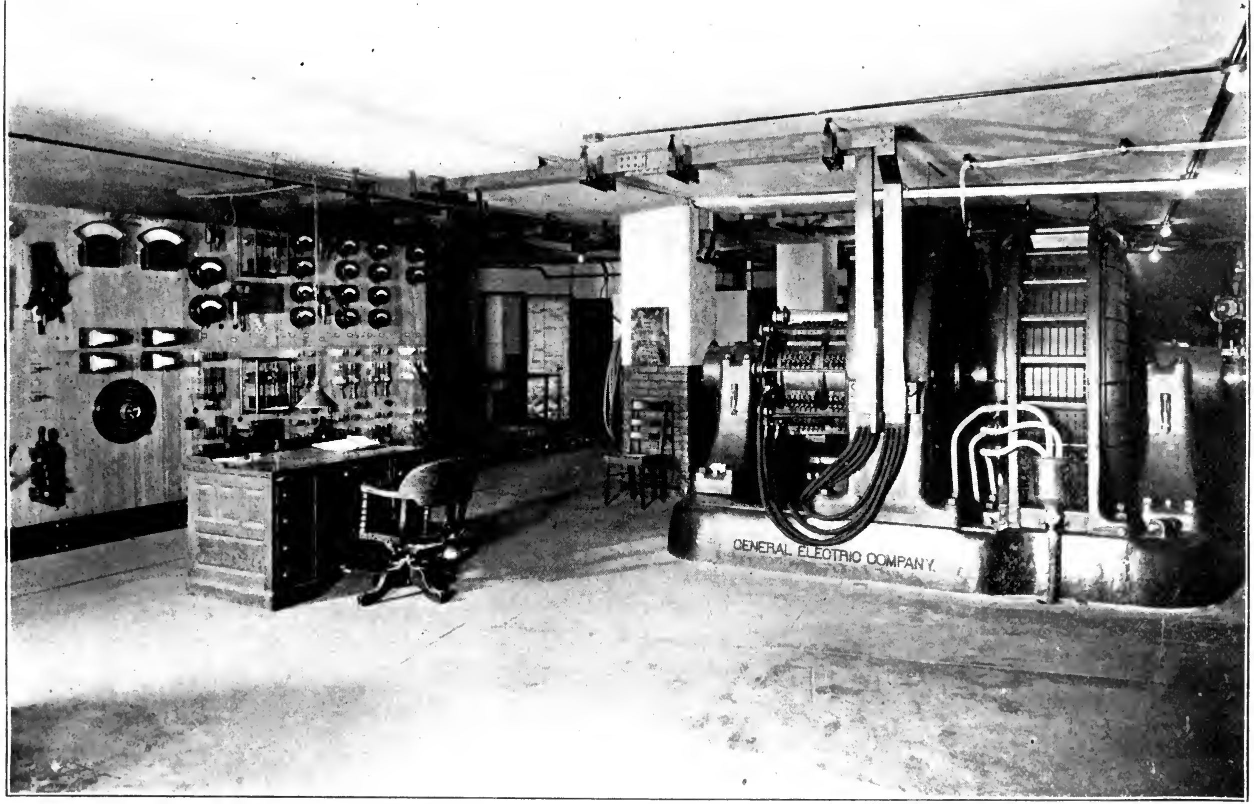
one hydro-electric station on the Connecticut River, in New Hampshire. These stations are connected to a 66,000 volt transmission line and are serving the electrical needs in portions of six states, extending into New York, on the west and the city of Providence, on the east.

The Turners Falls Power and Electric Company of Massachusetts, utilizes the water power of the Connecticut, Deerfield and Green Rivers for generating electrical energy, having hydro-generating stations on each of the rivers named. The energy is transmitted at 66,000 volts and is used in three of the New England States.

The distribution system of a central station is somewhat similar to the blood vessel relations to the heart of the human system, except that it is a system of cables, wires and other distributing means to carry electrical energy throughout the system from the main source of supply. Any interruption of this means of carrying energy means a congestion of the system which reacts back on the entire system. That this interruption may be reduced to an almost negligible possibility, stations and their equipments are now most carefully planned and installed. In doing this, the hazards are greatly reduced.

It is also interesting to note that the capacities of the generating units are increasing in size and potential, and we have not, apparently, reached the limit in size. In the first commercial Edison electric lighting station, which was started in Appleton, Wis., on August 15, 1882, the generating apparatus consisted of one dynamo driven by water power and had a capacity of 250 ten C. P. incandescent lamps. This was equal to 1 and ¼ K. W. The Hartford Electric Light Company operates 10,000 K. W. generators, while the Chicago Edison Electric Illuminating Company is using generators of 20,000 K. W. capacity.

In a modern generating station, the equipment is usually good from the viewpoint of fire hazard. The chief troubles often result from crowding the equipment and the installation of temporary work, always conducive to trouble when it is found necessary to enlarge the capacity of the plant. Ample room for operating and for inspecting is essential. Accessibility of all portions of electrical equipment, the use of fireproof materials throughout, the installation of protective devices of approved design, and of ample capacity and arrangement by




Courtesy of Commissioner James E. Cole, Wire Department, Boston, Mass.

Sub-Station of the Edison Electric Illuminating Company, Boston, Mass., showing a high-potential motor, directly connected to a low-potential generator. Note the pot-head treatment of the high-potential lead encased conductors on the right and the heavy low-potential copper conductors from the low-potential generator across the ceiling to the switchboard on the left.

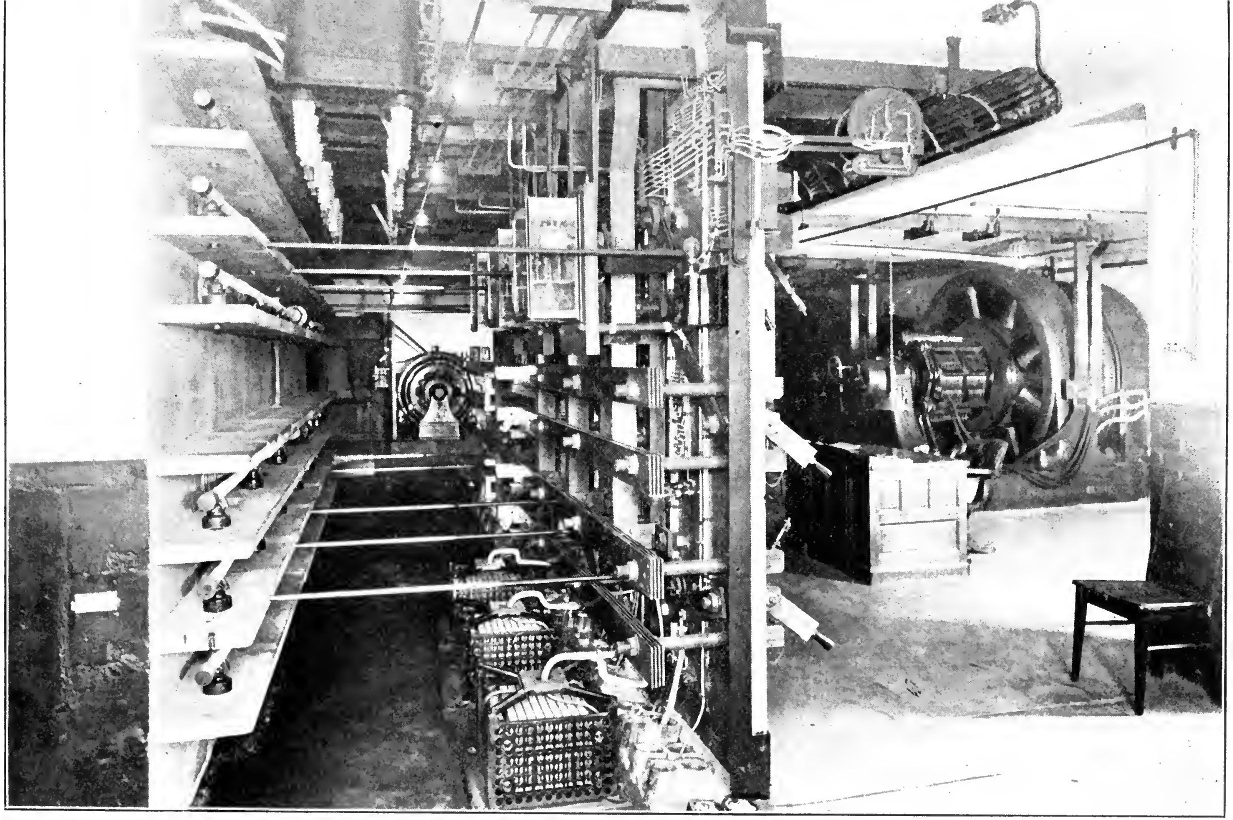
which any trouble may be readily confined to a limited portion of the equipment, are the chief requisites of a central-station equipment from the viewpoint of the electrical fire hazard.

We will recognize that the engineering requirements in special cases and the complexity and variety of equipments in the modern station render it manifestly impossible to be solved by a pamphlet the size of the National Electrical Code. In general, generators and motors of themselves present less hazards than the switchboards with the mass of wiring often found on them, the transformers with their charges of inflammable oil, the electrolytic lighting arrestors, or the large conductors carrying heavy currents and presenting large surfaces of inflammable insulations. It is, of course, extremely essential that the rules for safe wiring should be followed in all stations, and in fact, we should go further than the rules in order that every precaution may be taken to avoid interruption of service, often as serious with public corporations as the destruction of the station itself.

## GENERATORS.

Perfect insulation in electrical apparatus requires that the material used for insulation be kept dry. While in the construction of generators, the greatest care is taken that all current carrying parts are well insulated, still, if moisture is allowed to settle on the insulation, trouble is almost sure to occur. For this reason, a generator should never be installed where it will be exposed to steam or damp air or in any place where, through accident, water may be thrown against it. A location under steam or water pipes or close to an outside window should be avoided. No combustible material should be permitted near a generator as the hot particles of carbon from the brushes can ignite dust in grain elevators, wood-working rooms and other dust of an inflammable nature. A generator should be so located as to provide for ventilation, since the cooler a machine can run, the more efficient it will be.

The frames of generators operating at a high potential, in excess of 550 volts, should be grounded, since it is not practical to attempt to insulate them. Generators operating at a potential less than 550 volts should either have their frames insulated from earth or be permanently and effectively grounded.



Courtesy of Commissioner James E. Cole, Wire Department, Boston, Mass.

Rear of switchboard of sub-station of the Edison Electric Illuminating Company, Boston, showing treatment of exposed conductors, resistances and instruments. All parts of the switchboard are accessible, an important feature in a **generator station.**

In our former lecture it was stated that a constant-potential system was a system in which the potential (voltage) was always the same, the current increasing with the load. It is, therefore, necessary for some form of protective device to be provided so that these machines may not be overloaded.

## CONDUCTORS.

All wiring in a generating or sub-station should be installed in the most substantial manner, and care and attention should be given to simplicity and orderliness of arrangement. It should be readily renewable and accessible. All conductors should have ample current-capacity, and in their installation, care must be given to securing excellent insulation and reliable supports. Special regard should be given to the possibility of injury to conductors by tools, belts, ladders or from any other means which may cause a gradual wear of the insulation. The conductors from generators to switchboards, resistances or other instruments and thence to outside lines:

Must be in plain sight or readily accessible, or if properly insulated, lead encased cable may be laid in approved non-combustible conduits.

Where a number of wires are brought close together, as is generally the case in dynamo rooms, especially on or about switchboards, they must be surrounded with a tight, non-combustible outer cover (not to apply to low tension bus bars).

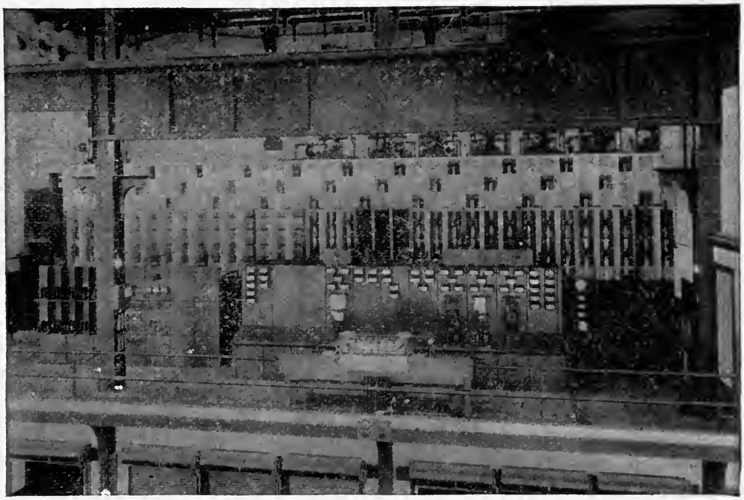
Wires shall be carried as direct as possible from the switchboard to the point at which they leave the building, and if leading to aerial lines shall incline downward to prevent the entrance of rain along the wires.

Must be separated from contact with floors, partitions or walls through which they pass, by non-combustible, non-absorptive insulating tubes such as glass or porcelain, with distance between sufficient to prevent possible contact. Must have no air space where they pass through floors from basement to switchboard other than that of the insulating tubes.

Other than for exciters all constant potential leads, with the exception of the neutral of a three-wire system and the grounded side of a railway system, must be protected by approved automatic cut-outs at the station.

## SWITCHBOARDS.

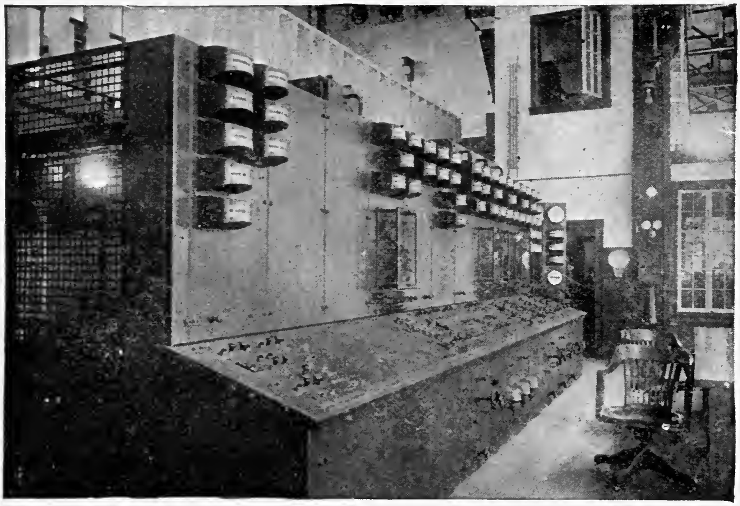
The danger of fire at switchboards lies in the large number of wires usually concentrated on them, and the use of devices and appliances which are possible sources of fire. A switchboard may be made of hard wood in skeleton form, in which case all switches, cut-outs, instruments, etc., must be mounted on non-combustible insulating bases. Switchboards are more generally made, however, of slate or marble, free from metallic veins. If metallic veins are not guarded against, they may cause great leakage of current, which will manifest itself in heating the slate or marble. The slate or marble is supported on metal frames.



Courtesy of Turners Falls Power & Electric Company.

View of the switchboard operating gallery in the high-potential generating station of the Turners Falls Power and Electric Company, Montague City, Mass.

A switchboard should be located well away from combustible material and should be open on all sides, that every part of the switchboard and its equipment may be accessible. There should be a space of at least three feet between the top of the switchboard and the ceiling, in order to lessen the danger of communicating fire to the ceiling. When the switchboard is back connected, there should be a clear space of at least eighteen inches. Every precaution must be taken to keep moisture or water from a switchboard, since this, of course, will result in a short circuit, as we are forced to have more or less unprotected contacts. While the front of the switchboard is the operating side, the rear is the part where trouble is more likely to occur. The back of the switchboard should, therefore, be easily accessible and neatness of arrangement and reliable supports for all conductors be imperative. No makeshifts should be permitted on a switchboard under any conditions. Absolute cleanliness, especially behind the switchboard, should be insisted upon. I can recall two fires, where the switchboards were located near windows, caused by snow being blown through broken lights of glass.

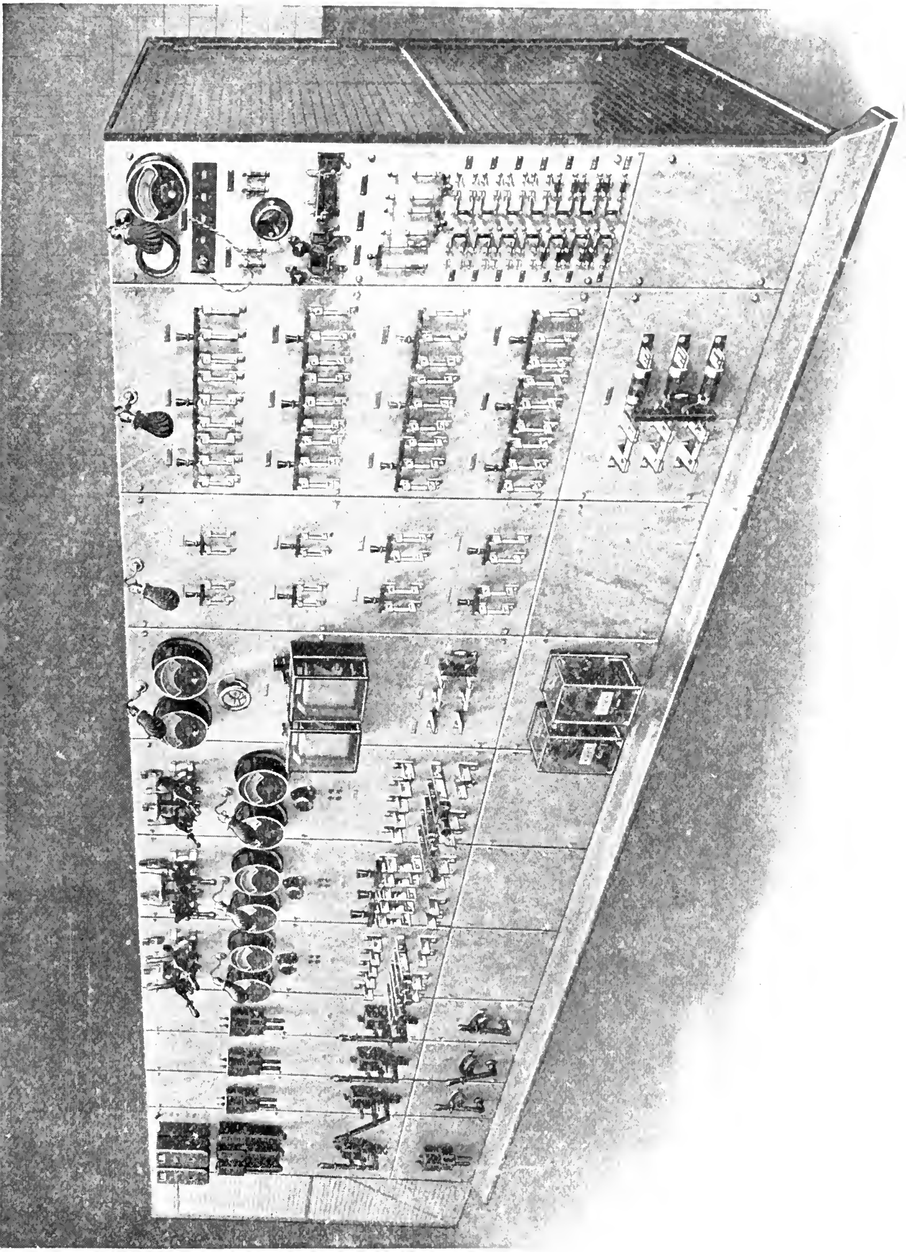


Courtesy of Turners Falls Power & Electric Company.

Bench board and operating desk in the generating station at Montague City, Mass.

## RESISTANCES AND EQUALIZERS.

Must be of approved type and not located in proximity to combustible material. Insulated wire for connection between a rheostat and its contact plate should have flame-proof insulation. These devices, which are used in great variety of sizes and designs, resemble the valve of a steam engine, in that they are regulators. In central stations where current is furnished over a large area, there is on some of the circuits, especially the long ones, a considerable "drop", or loss of potential. In order to keep the voltage at the point of supply on these circuits at the proper value, the voltage at the station must be raised. This, in turn, causes the voltage on these circuits near the dynamo to become excessive. Equalizers,



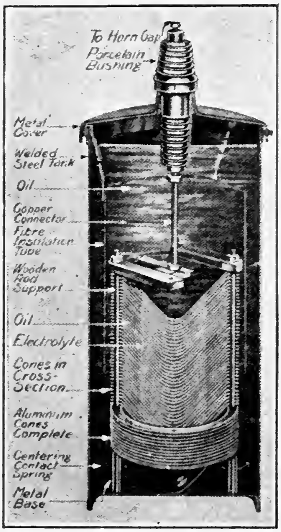
Courtesy of Trumbull Electric Manufacturing Co.

A marble switchboard, well arranged with remote control, high-potential oil switches on extreme left, automatic circuit breakers, knife-switches, meters and equalizers, located on the face of the switchboard. This switchboard is well away from the brick wall, thus making the rear of it accessible. The ends are protected by substantial wire grills, to prevent using the space back of the switchboard for storage purposes. This switchboard is in the basement of the Amoskeag Bank, New Hampshire.

which are large resistances generally constructed of iron or strips and capable of carrying a heavy current, are connected in the circuits and adjusted at such resistances as to make the voltage at the various points of supply uniform. They are generally too heavy to mount on the switchboard and are, usually, mounted above the switchboard on non-inflammable material. They are, in reality, sources of heat and should be so arranged and installed that even if overheated they cannot cause injury to surrounding objects. The burning out of a rheostat may cause a flame or flash, and oftentimes melted solder or other material is thrown off, which, if it comes in contact with combustible material, will start a fire.

## LIGHTNING ARRESTERS.

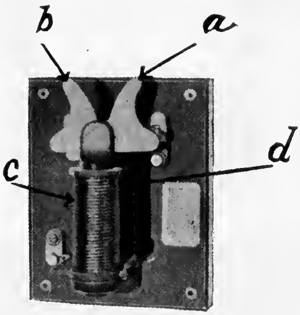
The purpose of these protective devices is to prevent lightning, or external high-voltage currents from foreign circuits entering the station and causing fire or damaging machinery and instruments. Lightning cannot be "stopped" but may be diverted to the earth. They should be connected to




Courtesy of The Insurance Field.

The latest form of lightning arresters which involves an entirely new principle for protection against lightning, is that known as the Electrolytic or Aluminum Arrester. This arrester is used chiefly on high tension transmission lines. The above illustration is a cross section view of the device, the "inverted dishes" are called aluminum cones. Arresters of this type should preferably be installed out of doors.

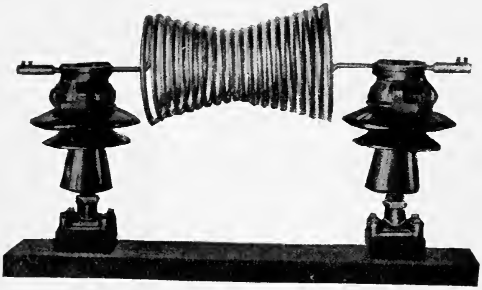
every overhead circuit connected with the station. The object of a lightning discharge from its beginning is to find its way to earth and if it can reach it more easily by some other path than by first going to the generator it will ordinarily take that direction. Electricity, no matter what its character may be, will choose the path of least resistance.




A lightning Arrester of the Magnetic Blow-Out Type has for its purpose the protection of circuits and apparatus against lightning and other abnormal potential rises of short duration. In the above illustration A and B are two copper wings separated from each other; the lightning coming in over the line B, jumps the narrow air space to A, from which it passes, by a wire connected to a water pipe or other proper earthing provision direct to ground. The electro magnets, C and D, are excited by a current from the generator and serve to "blow-out" the arc between the wings so that the generator current cannot follow to earth. The air space between the wings where they come nearest together is made great enough to prevent the generator current from jumping it of its own initiative, it being well known just how far through air currents at different voltages can jump; but if the arc is first established the gases generated greatly lower the resistance of the path across the air space and, were some means not provided for extinguishing this arc formed by the lightning discharge, it would be maintained by the generator current after the lightning discharge had ceased and therein is the main fire hazard from this apparatus.

In order to increase the difficulties of the lightning discharge reaching the generators, it is customary to introduce directly in the wire at some point between the arrester and the machine a coil of wire known as "reactance" or "choke coil", the object of which is to choke this discharge back from the machine to the easier path provided through the arrester. While there are a number of types of arresters, the main principle embodied is common to them all; that is, a resistance and an air gap across which the current must jump to reach the earth. When the discharge jumps the air gap, an arc is formed and if the arrester is not designed to promptly extinguish this arc, the generator current is likely to follow and if there is anything combustible in the immediate vicinity, fire may readily ensue.

The arresters must always be connected with a thoroughly good and permanent ground connection, and this ground wire must be run as free as possible from kinks, coils



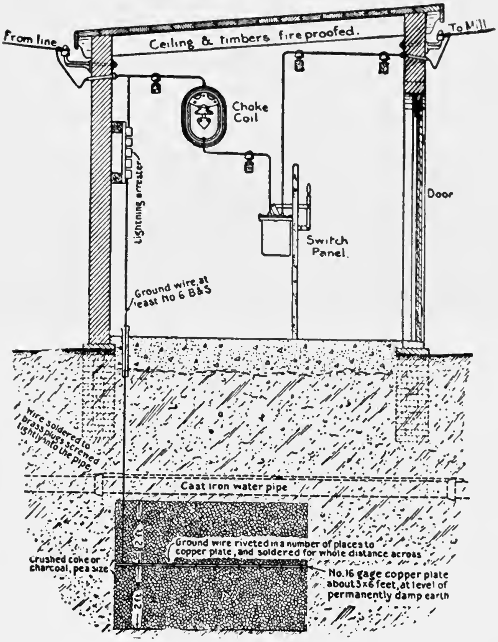
Courtesy of The Insurance Field.

Choke coil for the purpose of diverting lightning discharges from the line to the ground.

and sharp bends. The ground connection should not be connected to gas pipes, as there is always a liability of a very severe discharge, which, with a gas service, may result in melting the gas pipe and igniting the escaping gas, thus causing an explosion or a fire.

## TESTING OF INSULATION RESISTANCE.

Except where circuits are intentionally and permanently grounded, a "leak" to "ground" may be the cause of arcs at any point in the system which may be dangerous. The amount of leak varies, but is always dependent on the insulation resistance. Where a small amount of wire is well installed, the leak should be very small, but in the case of large installations or where the wiring has been poorly done, the flow of current to ground or between wires of opposite polarity may become quite large. Wires lying on pipes or on damp woodwork, crossed wires or live parts of apparatus mounted on wooden blocks, all tend to cut down the insulation resistance and increase the leak. The effects of poor insulation are; First, it represents a useless loss of current, and second, and more important, it means a possible cause of fire. All circuits, therefore, should be so arranged that they may be tested as to their freedom from grounds and leaks.




Courtesy of The Associated Factory Mutual Fire Ins. Co.

Method of connecting the lightning arrester, choke-coil, and ground wire to outside line and earth; also showing an oil switch and line to mill.

An oscillatory discharge of lightning taken by the author in the city of Hartford, July 18, 1908.

## Part No. 3.

## ELECTRIC MOTORS.

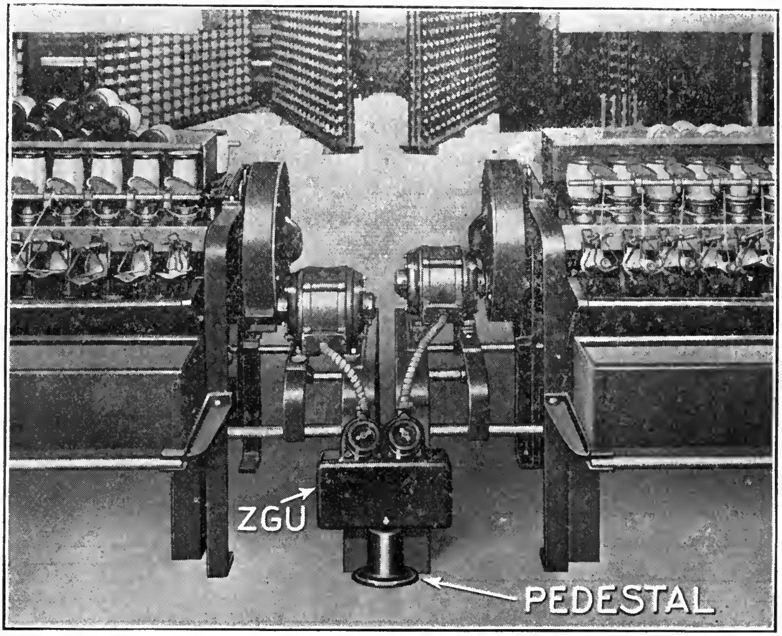
To trace the history of the electric motor would require a volume in itself, and that too, one of no mean dimensions. The early history of invention in the line of electric motors include a number of well known names, the most prominent of which, as I now recall them, are Jacobi, Ritchie, Wilde, Dal-Negro, and, coming down to the present day, the well known inventors whose successful electric motors are now occupying so important a field in various lines of work.

I am unable to recall an electric device which is so intimately related to our every day industrial life as the electric motor. Its development and popular use has increased far beyond my ability to relate. They are now very generally used in manufacturing plants of all kinds; they are to be found on the farms, far back in the country, and in our homes performing simple tasks in an economic manner. Their use is increasing, as is also their opportunity, due largely, I believe, to the many hydro-electric developments, with their far reaching transmission lines.

Portable motors of small size have come into general use for drills, portable tools, vacuum cleaners, washing machines, sewing machines, massaging appliances and many other purposes where their cleanliness, economy and adaptability to all service recommends them. These portable motors, however, do not come under the rules prescribed for stationary motors, though their use involves similar hazards and some others peculiar to themselves.

In some respects, a motor should receive the same consideration as a generator, in that it should be located in a clean, dry place, although motors are so constructed that they can be operated out of doors and even where moisture is present. Except when unavoidable, motors should never be located in a dusty or linty place, and when so located should be enclosed in a separate room, which room should be largely of glass, so that the condition of the motor may be noted from the outside.

We are now having a number of 2300 volt installations for power and the requirements for these are greatly different from those for motors which operate at a potential of 550 volts or less. The wiring for motors of the lower potential may be what is termed "open work", which consists of exposed wires supported on porcelain cleats or knobs. When we purpose using motors of the higher potential, however, the wiring must be in multiple conductor, lead-sheathed, cable, installed in an approved metal conduit, unless the installation be in a central or sub-station where the men employed would be familiar with the life hazards involved, when the installation may be in open wiring. The lead sheathing of the multiple conductor cable and the metal conduit must be effectively grounded, that, in event of either becoming of a potential, the current may be shunted to earth.




Courtesy of Crouse-Hinds Company.

The application of electricity in cotton mills has been the subject of study by Electrical Engineers for many years. This is because of the deposits of lint which settle on all wires, switches, cut-outs and other fixtures, ready to burst into flame at the first spark. In the above method of installation all live current-carrying parts are well protected from dust and lint as well as from mechanical injury.

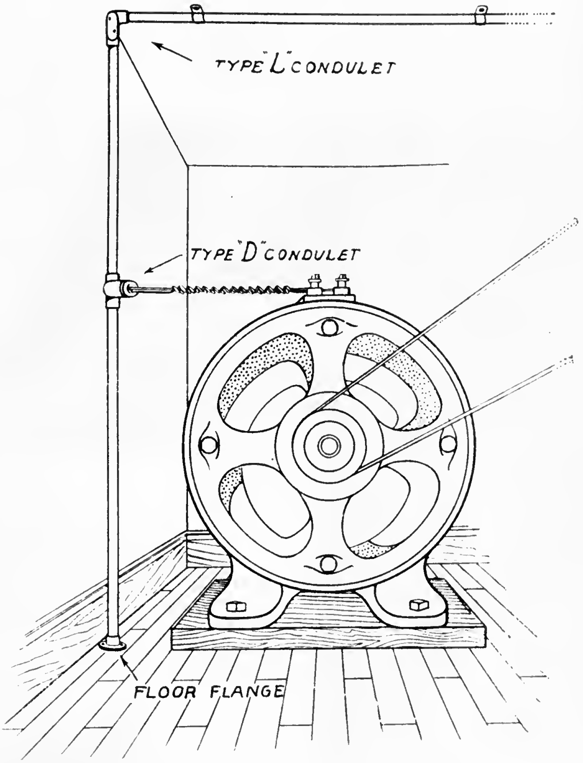
The conduit system must be connected to the motors, starting devices, switches, circuit-breakers and all appliances, that there will be no exposed wiring. There are no motors in commercial use between 550 volts and 2200 volts, and, when making the rules, it was not thought too much to ask that a form of construction and installation which would provide for the greatest amount of protection to the wires and the several appliances should be provided.

Care should be exercised at all times to have the wires of the motor circuits of sufficient size that they can care for the starting current, which is always in excess of the full running load. For this reason the rule requires that the conductors carrying the current of only one motor must be of sufficient size to carry a current at least 25 per cent. greater than for which the motor is rated. This requirement applies more especially to motors connected to direct current systems. For motors connected to alternating-current circuits, where the starting load is some times 350 per cent. greater than the full running load, attention must be given to proper protection, in the form of fuses or circuit-breakers of the circuit wires. Where the conductors under the rule would be overfused in order to provide for the starting current, as in the case of many of the alternating current motors, the conductors must be of such size as to be properly protected by these larger fuses.

The use of motors operated on current taken either from the trolley, or from a generator directly supplying the trolley system, is prohibited, owing to the fact that the trolley system is always a grounded system and the current is too dangerous to bring inside buildings. One side of the circuit being normally grounded, there is always a tendency for the current that enters the building, if opportunity offers, to find some path to earth and return to the generator by that path. This increases the fire hazard. These circuits are also more likely to suffer from lightning. In street railway repair shops, of course, these motors are permitted because the trolley current is one of the hazards inherent to the risk, and this is taken into consideration in classifying the risk.

The protective devices for motors are especially necessary, since the load is usually thrown on or off, and this load may be in excess of that for which the motor was designed.

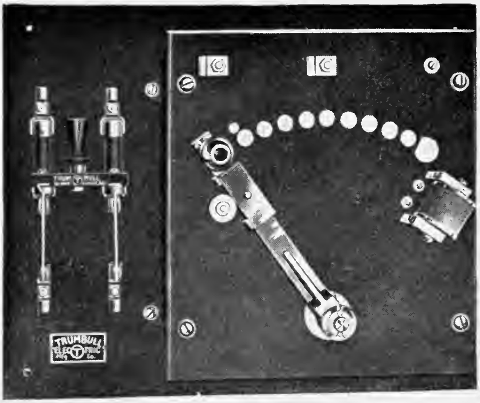
These protective devices are either in the form of fuses or circuit breakers, both being automatic in operation. Circuit-breakers are to be recommended, as, when the breaker opens, the service can more easily be put again into commission. A reference to the rule will show that the starting device for the motor must be located in sight of the motor, except where special permission is given to deviate from this rule. As can be readily understood, it is not usually considered safe for a motor to be started with the operator not in sight of the motor, in the event of there being any derangement of the shafting, pulleys, belting, etc., or should the motor fail to start and thus heat, the operator will be in a position to disconnect the circuit, through the switch, before serious damage has been done.




Courtesy of Crouse-Hinds Company.

Method of installing conductors in conduit to a motor with the use of a floor flange which adds rigidity to the conduit.

A starting device is an appliance for limiting the current strength during the starting of the motor by inserting a resistance in series with the armature. For motors connected to direct current systems a starting-box, or rheostat, is used, while for motors connected to alternating current systems, the starting device is somewhat different and has somewhat the form of a transformer.

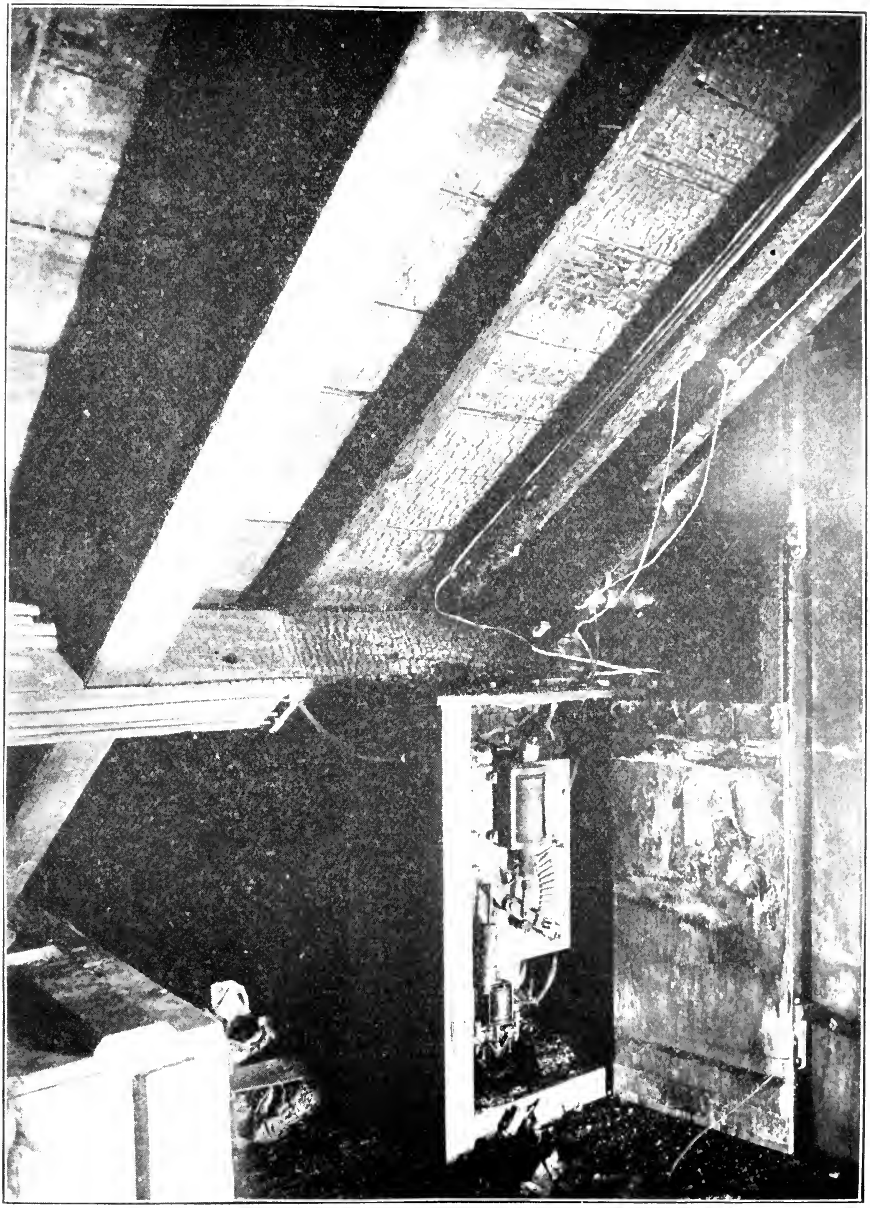


Courtesy of Trumbull Electric Manufacturing Company.

Installation of a starting rheostat upon a slate slab, thus protecting combustible material from the heat in the starting device—the protective fuses and starting switches are on the left of the rheostat.

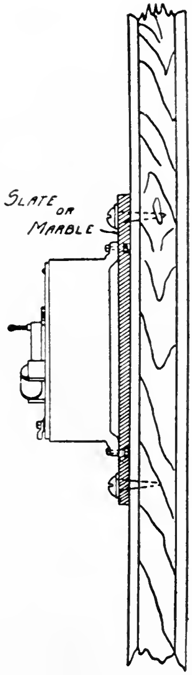
In a former lecture, reference was made to the need of treating resistance, or rheostats, as being sources of heat and should be located away from combustible material. This is usually done by mounting the rheostat on a continuous piece of slate or marble, the slate or marble then independently secured to the wall, never using, however, the same screw for attaching both. Motor starters for direct current motors should also be provided with a no-voltage release. This in its simplest form is a magnet across the line which holds the lever arm of the rheostat. When the current fails, the lever arm is drawn back by a coiled spring. Another device, known as the "overload release" is frequently attached to a rheostat, its intended office being to release the arm of the rheostat should the load become greater than that for which it was designed.

I have mentioned that the starting devices for alternating current motors differed from those for the direct current motors. These alternating current devices are called auto-starters. Instead of an ohmic resistance, an inductance is used to keep the current from attaining excessive value while the motor is coming up to speed. These devices are generally so constructed that the operator cannot leave them in a position where any current passes through the starting device. They are usually oil immersed, so that in case of trouble there is considerable combustible material. In general, motor



Courtesy of Commissioner James E. Cole, Wire Department, Boston, Mass.

Rheostat used in connection with motor was defective, the greater portion of the coils being open-circuited, motor not taking current until contact finger was on next to last button of contact points. Motor was started shortly before fire was discovered, and excessive sparking at commutator, due to defective condition of rheostat, occurred. Fire was caused by these sparks igniting oil, lint or other inflammable material in vicinity of motor.




Rheostat properly mounted.

starters, either for direct current or alternating current circuits, present the hazards of switches and possibly overheated coils, and must be so considered and treated accordingly.

## RAILWAY POWER STATIONS.

In the city of Meriden, Conn., years ago, there was an ungrounded trolley system which had a double overhead trolley. Such a system has been advocated and even tried in several other places, but, in each effort, operating difficulties presented themselves. The system had two overhead wires, while the cars had double trolleys. With this arrangement, the tracks had no part in the return circuit, and the current was kept free from ground. Practically all of the railway power stations now operate with a ground return, so that in case of a ground on any feed wire, we will have a dead short-circuit. For this reason and on account of the load carried, the protection device must be of the circuit-breaker type.

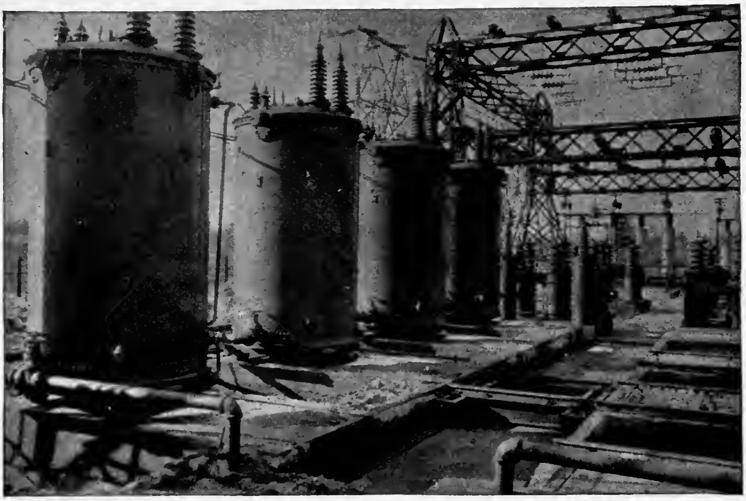
## STORAGE OR PRIMARY BATTERIES.

Batteries of large size are now to be found in common use. These are practically always storage batteries, that is, batteries which are recharged by having current from a generator supplied to them from time to time. It always gives out direct current in the reverse order from which it is charged. Primary batteries are very limited in their capacity and are used chiefly for signaling systems when current from generators is not available. Storage batteries are now found in the high voltage generating and transmission stations for the remote control of the high voltage oil switches and circuit breakers. They are also used to assist a station during what is called the "peak load". They are also used in most of the telephone exchanges and on many of the automatic fire alarm systems. A storage battery may very properly be called a reservoir of energy, capable of producing trouble if their output is not properly controlled.

The action of the current in charging the battery liberates at time large quantities of hydrogen and oxygen, and if these should accumulate in the right proportions they would form an explosive mixture which might be exploded by any accidental spark, for this reason, therefore, storage battery rooms must be thoroughly ventilated. As practically all of the batteries in use contain sulphuric acid, it is necessary to provide in the battery rooms for the protection against corrosive vapors. The water and acid in the rooms require that the wires should be especially well insulated.

## TRANSFORMERS.

At this time, we are to consider the fire hazards introduced by transformers as they concern central and sub-stations, in which stations the transformers must be so placed that smoke from the burning out of the coils or the burning over of the oil (where oil filled cases are used) could do no harm. Most of the transformers used in central or sub-stations contain oil for insulation and, sometimes, for cooling. As the amount of oil in large transformers is considerable, and as it will cause a very hot fire, should it become ignited, it is necessary to so locate these transformers, that in case of a burn-out, the burning oil or insulation will not endanger the balance of the plant. In central stations, where there is other equipment, the transformers are generally placed in transformer rooms, which rooms should be well ventilated to the outside air to prevent the accumulation of explosive vapors, which may be given off from the oil when hot, and to facilitate keeping the room cool, thus preventing overheating of the transformers. These rooms should be of fire resisting material.



Courtesy of Turners Falls Power & Electric Company.

66,000 volt transformers used by the Turners Falls Power and Electric Company in its outdoor station at Chicopee, Mass. The supply of electrical energy for these transformers is from the hydro-electric generating station on the Connecticut River at Montague City, Mass.

Provision should be made to prevent the spread of the burning oil, also for quickly emptying the transformer cases of oil through the means of quick-acting valves which can be operated outside of the transformer rooms. In many of the high-potential transmission companies, the large capacity transformers are now located out-of-doors and are called "out-door stations", in which stations care should be taken to prevent burning oil from flowing to any buildings which may be near.

## OUTSIDE WORK.

The rules for Outside Work are intended to safeguard risks which may be exposed to hazards of outside electrical conditions and are to be applied to all systems and voltages, but are not to be considered for installations for Light, Heat or Power protected by the service cut-out and switch, which will be explained during a later lecture. There are several ways in which outside wires may be a menace to buildings. First.—By producing abnormal conditions on the inside wiring, as when one wire becomes grounded, there already being a ground on another wire of this circuit inside the building: A short circuit of wires outside causing the fuses inside to blow. Special care should be taken to prevent a short-circuit between open wires occurring close enough to woodwork of buildings to ignite it. Second.—By the crossing of a high-potential wire with a low-potential, the cross being when one wire of the high tension circuit touches or comes in contact with a wire of the low-potential circuit. As an example, I might cite the case of a 2300 volt circuit in contact with a 110 volt circuit, which 110 volt circuit was intentionally grounded on a water pipe in the building which it served.

This cross was made possible by the sag of the wires on the pole line during a heavy snow and rain storm. The other wire of 2300 volt system was grounded on the limb of a tree which was heavily covered with wet snow. This established a high potential cross and the wires of the low potential circuit rose to the higher, 2300 volt circuit. There were arcs established in the fuses which blew, and the fixtures and sockets, which arcs caused a number of small fires throughout the one building, there being but one building on that secondary system.

Another example is that of a telephone wire becoming crossed with a wire of a lighting circuit, either of low or high potential, and, unless the telephone was properly protected where it entered the building, arcs or grounds would then be easily established and fire ensue as a result. Third.—By wires coming in contact with buildings, starting arcs or grounds through damp woodwork or conductors, flashings, etc.

## CARE IN CONSTRUCTION.

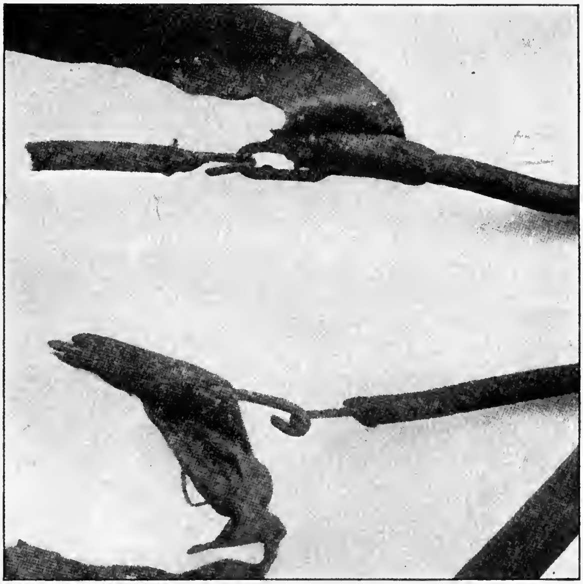
For these reasons, it is extremely important for all outside wires to be run in a substantial and careful manner, especially so as not to interfere with the operations of a Fire Department in the time of a fire. We sometimes find men who are careless in that particular, seeking to construct the outside lines in the easiest possible manner, regardless of looks or safety. We can now appreciate the placing of all outside wires underground, the electric light and power circuits installed in one set of conduits, and what is called signaling wires in another set of conduits, both systems of conduits being independent of the other, each system being provided with separate manholes. These signaling systems include the telephone, the telegraph, district messenger, fire and police alarm, clock and burglar alarm systems. The underground system is expensive to install and may only be found in cities of the larger size.

The next best method is one we sometimes see, that of having one set of poles for the electric light and power wires and another set for the signaling wires, thus keeping the several systems separate. The objection to a system of this character is largely one of appearance, it requiring two sets of pole lines, one on each side of the street. It is a general practice, however, when the wires are not underground, to run both the electric light and power wires and the wires of the signaling systems on the same set of poles. In such cases, the signaling wires should not be placed on the same cross-arm with the electric light and power wires.

## OUTSIDE WIRES.

Line wires may have either rubber insulating or weatherproof covering. The standard practice has been, however, to use the latter, which consists of three cotton braids, each thoroughly impregnated with a water-proof compound. This covering is depended upon for accidental contact but not for insulation proper. The conductors for the extra-high potential transmission lines, however, are without covering of any nature, but such lines are not to be seen in congested areas, except they be upon very high poles, when the lines are at the top out of reach of linemen when working on other lines. All tie wires, as at insulators, must have an insulation equal to that of the wires they confine. While rubber insulation may be used, it is much more expensive and in a few years would be no better than weather-proof.

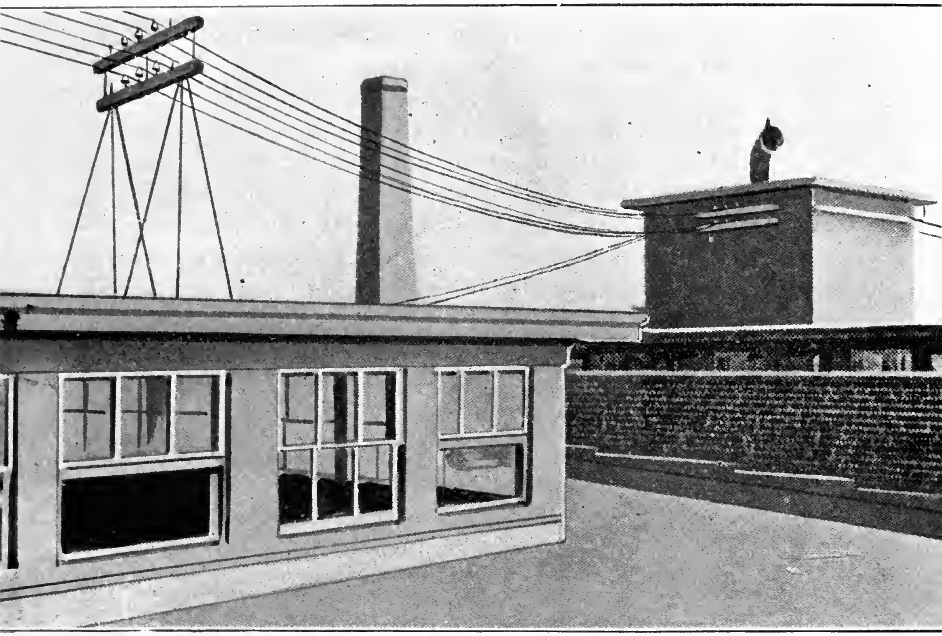
It is the general practice to support the outside wires on glass or porcelain insulators at least 1 foot apart on pole line cross-arms. These insulators are called "petticoats" and will nearly always have a dry space underneath their lower edges, and even if not dry, the length of the path offered to the current escaping over the wet surface is so great that the leakage is small.



Courtesy of Underwriters' Laboratories, Inc.

Two splices, found in a department store, made by the "handy-man". Splices improperly made are extremely hazardous because of the insecurity of contact, the wires will heat and ignite the insulation, over which the flame will travel.

All joints should be well made and soldered as an unsoldered joint is liable to become loosened or corroded, in either of which events the contact between the wires would become imperfect. This would cause heating at the joint and might result in the wire being completely melted off and a dangerous arc being formed at the break. A good mechanical joint is required for strength should the soldering give way or become corroded by traces of acid in the soldering fluid or flux used.



Courtesy of The Insurance Field.

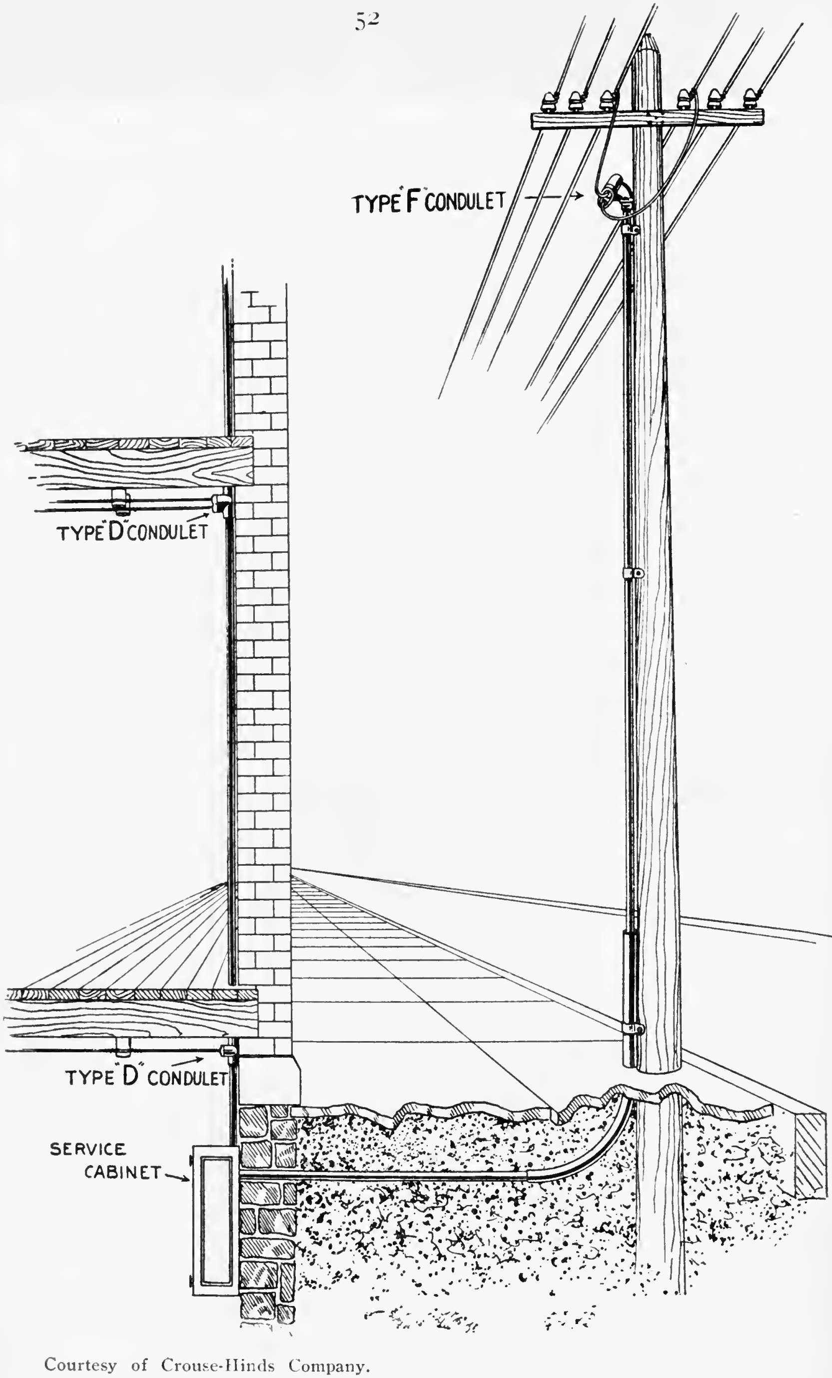
Outside lines well supported over roofs.

Where outside lines are supported on buildings, they must be at least 8 feet above the highest point of roofs over which they pass or to which they are attached, and roof structures must be substantially constructed and wherever feasible, wires crossing buildings should be supported on poles independent of the building.

This is intended to insure that under no conditions could the wires sag and touch the roof; and also that persons walking on the roofs could not come into accidental contact with them. Roof structures are sometimes found which are too low or much too light for the work, or which have been carelessly put up. A standard structure which is to hold the wires a proper distance above the roof in all kinds of weather must not only be of sufficient height, but must be substantially constructed of strong material.

Where outside wires are brought into buildings, special precaution must be taken. These wires are known as service wires or services, and should be kept free from contact with anything but their designed supports. Frequently these wires

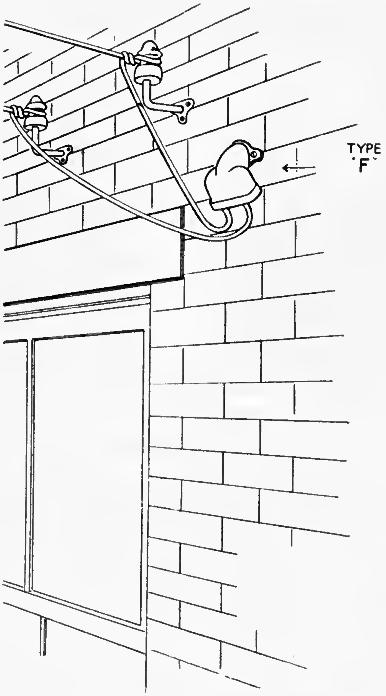
Courtesy of Commissioner James E. Cole, Wire Department, Boston, Mass.




Courtesy of Crouse-Hinds Company.

A good method for bringing service wires underground from an overhead line to the cellar of a building. The exposed end of the conduit has a terminal fitting which prevents water flowing into the conduit.

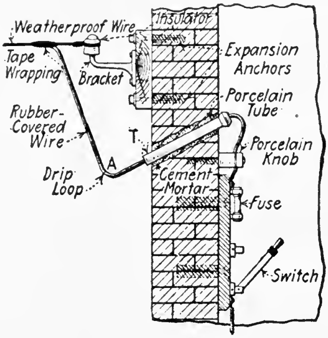
are found to be in contact with the building, signs, shutters and awnings offering an opportunity for a fire, through the medium of an arc. That portion of the service wire from the last outside support into the building must have rubber insulation as an extra precaution. One method used to bring these wires into a building is to have them enter through bushed holes, with the porcelain bushings slanting upward toward the inside, the service to have "drip loops" also that water may not follow the wires inside the building and establish an arc around the service cut-out and the wet wood.




Service wires secured to side of building by petticoat insulators and entering building through terminal fitting which prevents moisture in conduit through brick wall.

Another method is to install the several wires in a metal conduit, this conduit extending from the basement where the wires enter, up the side of the building well out of the reach of persons. On the upper end of the conduit a fitting known as a "pipe cap" should be installed, which fitting protects the wires, in the conduits, from moisture.

Where lead covered cables are strung overhead, the outside sheath should be permanently and effectively grounded, as any breakdown of insulation between the conductor and the sheath makes the cable practically a bare live wire, the dangerous condition of which is obvious. The ground connection required by this section keeps the sheath at the potential of the earth and prevents a dangerous flow of current from the sheath at any other point. The ground wire should be of sufficient size and so well connected to the sheath and to the earth that it can safely carry the current necessary to melt the fuses protecting the cables.




**Weatherproof and Rubber-Covered Wire at Service Entrance.**

Details of service wires entering building.

Trolley wires must be of ample size for mechanical strength and are usually No. O B. & S. gage copper or No. 4 B. & S. gage Silicon Bronze. Protection against crosses must be ample and street railway trolleys and feeder cables must be capable of being disconnected at the power stations or of being divided into sections so that, in case of fire on the railway route, the current may be cut-off from that particular section and not interfere with the work of the fire department.

## ELECTROLYSIS.

Electrolysis is the chemical decomposition of a conducting substance caused by the flow of current through. One specific form of electrolysis is the "eating away" or corrosion of underground metallic structures due to the passage of stray electric currents from them. The other important form of electrolysis is the decomposition of electrolytes by electric currents; electroplating and electrotyping are practical examples of this. If a current passes from one conductor (positive plate or anode, Fig. 1, I) through an electrolyte to another conductor (negative plate or cathode), the electrolyte will be decomposed and the anode may, under certain conditions, also be decomposed.

Example.—If a current be forced from one platinum electrode to another through a copper sulphate electrolyte, as shown in Fig. 1, I, metallic copper will be dissociated from the solution and deposited on the cathode. The remaining components of the copper sulphate will unite with the water in the solution to form sulphuric acid. This illustrates how an electric current can decompose electrolytes. This principle can be readily demonstrated (Fig. 1, II) by using a couple of dry cells as a source of energy, a couple of iron nails as electrodes and a solution of blue vitriol (copper sulphate—a crystal the size of a walnut in a tumbler full of water) for an electrolyte and a glass tumbler for a jar.

Electrolytes are solutions in water of acids, bases, (alkalies) and salts. They are decomposed when an electric current passes through them. The exciting solutions in primary and secondary cells and the solutions used in electroplating and electrotyping are examples of electrolytes.

Electrolysis of underground metallic structures is illustrated in Fig. 2. Direct current railway systems practically always use the track as a return conductor. The return current "leaks" from the track, which is always in contact with the earth, and often seeks a route of minimum resistance through water mains, cable sheaths and other metallic underground structures. Where these leakage currents enter the buried metallic systems (A, Fig. 2) there is no trouble. But at locations (B) where the stray currents leave, electrolysis, wasting away of the metal, occurs.

The action is similar to that of an electroplating process. The water main in the illustration B is the anode. The chemical salts in the earth in the combination with the moisture in it constitute an electrolyte. The ground plate or connection at the generating station is the cathode. With large railway systems the leakage may be very great, in which case the consequent eating away of underground metals is extensive. In some cases, a service water pipe may be eaten entirely through in a month. This, you will at once recognize,

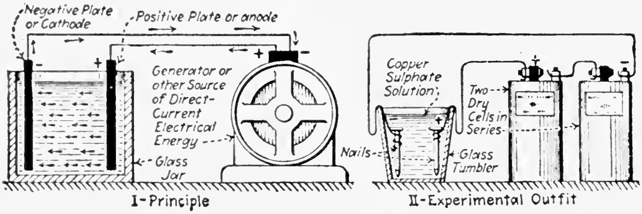



**Fig. 1—Illustrating Electrolysis.**

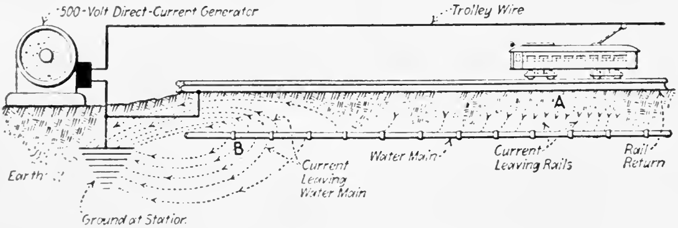



**Fig. 2—Illustrating Cause of Electrolysis of a Water Main.**

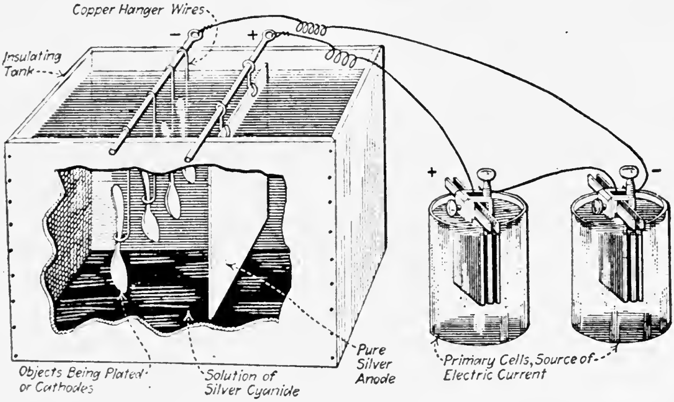
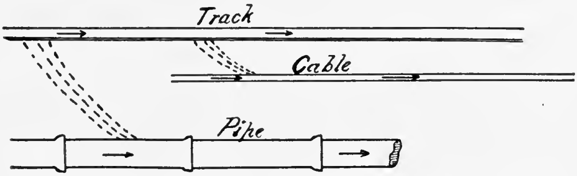



**Fig. 3—A Silver Electroplating Outfit.**




Courtesy of The Insurance Field.

If as shown in the above diagram the tracks of a street railway, a line of water pipe and a telephone cable, all form conducting paths toward the power house, the current on the tracks will divide itself up and the greater part stay on the tracks, but part of it taking the pipe and part the telephone cable.

bears a very close and a very vital relationship to the public fire protection systems. The most effective method of correcting such electrolytic action is to minimize the tendency for its occurrence. Just how this may best be accomplished all engineers have not agreed, although a number of plans have been tried. One method has been that of providing a low resistance path back to the generating station by connecting the station ground directly with the rails at various locations with heavy copper return conductors and bonding the rails. The double overhead trolley has been tried and, while this did solve the problem, in so far as electrolysis was involved, it introduced several other difficulties. The United States Bureau of Standards is recommending a system of transpositions, or reversals, and this method is being installed in the city of Springfield, Massachusetts. This method, I believe, had its origin in Germany, but most of us are not concerned, at this time, in anything that had its origin in Germany.

Whenever a current passes through a solution of a salt of a metal, the metal will be extracted electrically from the solution and deposited on the negative plate or cathode. Fig. 1 illustrates a sort of electroplating process. Electroplating consists in coating by electrolysis a baser metal with copper, gold, silver, nickel or almost any other metal.

Example.—Fig. 3 shows a silver plating outfit. In modern commercial outfits low-voltage, direct-current generators are practically always used as sources of current instead of primary cells. The process is about as follows: The surface of the object to be plated is thoroughly cleaned of all fatty matter. The object is connected to the negative pole of the source of electrical energy and thus constitutes a cathode. The electrolyte is a solution of some chemical salt of the metal to be deposited. For silver, cyanide of silver is used; for copper, copper sulphate, etc. To maintain the strength of the solution, a piece or anode of the metals to be deposited is attached to the positive pole of the electro-motive-force source. (Note:—Electro-Motive-Force is generally expressed as E. M. F.) The current in flowing through the solution deposits the metal of the solution on the cathode. Certain metals such as iron, steel, zinc and lead cannot be plated with certain other metals, such as gold, silver and nickel, until after they have first been given a thin plating of copper.

Electrotyping is an electrolytic process, similar to electroplating, whereby wood cuts, type and like objects can be reproduced in metal, usually copper. An impression of the object to be reproduced is taken in warm plaster of paris or similar molding material. The surface of the mold thus made is thinly coated with some fine metallic substance, such as powdered graphite, to render it conducting. The mold is then immersed in a copper sulphate solution bath and its conducting surface is so connected to the negative pole of a source of electric current that it constitutes a cathode. It is then treated much like any other object to be plated. When the copper coating on it has become about the thickness of a visiting card, it is removed and reinforced by pouring molten metal on its back. If it is to be used for printing it is backed so as to be the same height as type.

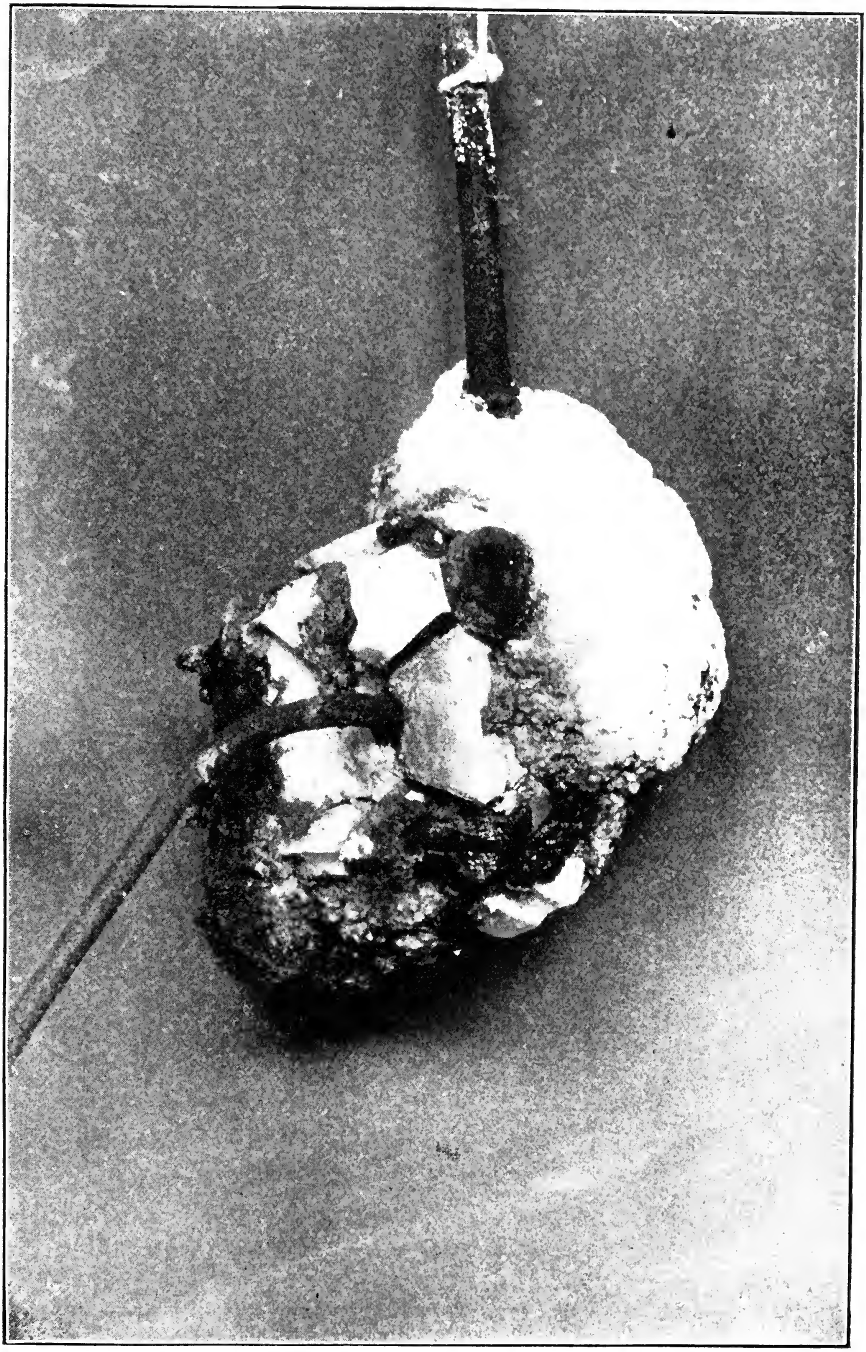
In the electrolytic refining of metals the process is somewhat similar to electroplating (Fig. 3). The impure metal to be refined is suspended as an anode in a solution of its salts. Current is forced through the solution from the anodes to the cathodes. Pure metal only is deposited on the cathode. The impurities of the anodes fall to the bottom of the tank as the pure metal is extracted from them. The electrolytic refining of copper is a very important process commercially.

## HIGH TENSION LINES.

A reference has been made to high tension lines, more especially to the overhead lines of this class which, unless properly arranged, may increase the fire loss.

> "Accidental crosses between such lines and low-potential lines may allow the high-voltage current to enter buildings over a large section of adjoining country. Moreover, such high-voltage lines, if carried close to buildings, hamper the work of firemen in case of fire in the building. The object of the rules is to so direct this class of construction that no increase in fire hazard will result, while at the same time, care has been taken to avoid restrictions which would unreasonably impede progress in electrical development."

The very best way to guard against accidental contact and crosses between the high-tension lines and other circuits is to have them follow different routes. This, however, is not always possible, but it has been accomplished by mutual agreement of the parties interested even when a change in



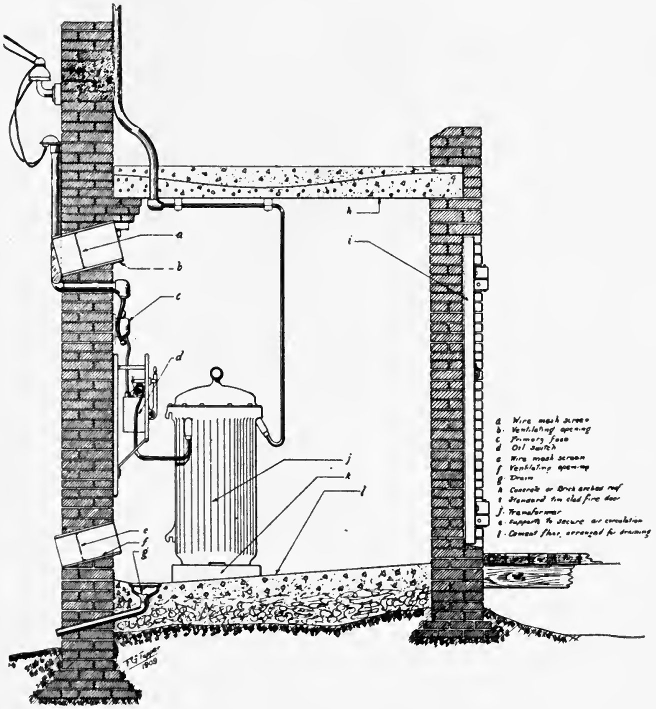
Courtesy of Commissioner James E. Cole, Wire Department, Boston, Mass.

Collection of salts on wire in a damp basement, illustrating a form of electrolysis.

one of the routes will be necessitated. When, however, these lines do cross each other, special precautions must be taken to prevent contact between the two lines especially should one of them break. The rules contain detailed specifications for the safe construction of crossovers and other details of high-voltage lines.

## TRANSFORMERS.

Transformers should preferably be kept outside of buildings. In general, it is dangerous to locate transformers with oil-filled cases inside, as it is entirely possible for a breakdown of insulation to ignite the oil, which may result in a very stubborn fire. For the same reason, the placing of transformers on roofs is also objectionable. Sometimes we face conditions which make it necessary to install these trans-




Courtesy of The Insurance Field.

Method of installing an oil insulated transformer in a vault of fireproof construction. Transformer, however, should never be installed in a building unless in a fireproof vault as shown above.

formers within buildings. When this is done, the transformers must be installed in a fire-proof vault, having a standard fire door, with a raised sill across the doorway to prevent burning oil from flowing into the building. These vaults should be well ventilated to the outside air and, if possible, should be drained that the burning oil may flow from the vault without doing further damage.

## GROUNDING OF SECONDARY CURRENTS.

The grounding of secondary currents is for the purpose of providing protection to human life from electric shock. The grounding of the secondary leads to a harmless point all stray currents from any source which may become crossed with the secondary service.

As early as 1900 this practice was found to be beneficial by actual experiment and test, and in 1905 the subject was discussed in meetings of the national electrical engineering societies. From that date the practice of grounding secondaries became more or less general; beginning with 1907 various engineering organizations recommended the practice as desirable, and in 1915 such organizations as the American Institute of Electrical Engineers, the National Electric Light Association, and the National Board of Fire Underwriters recommended that the practice be made mandatory.

The secondary voltage value should determine the question of when to ground the service, and it is now standard practice to ground all secondary service in the lower voltage group, up to and including 150 volts.

There are three points at which a secondary system may be grounded, namely,

At the generating station,
At the transformer,
On the customer's premises.

If the generating-station grounding point is used, it is necessary to have the overhead grounded wire running over all the lines carrying the secondary system, which subjects linemen and overhead workers on pole lines to an unnecessary hazard, brought about by the presence of this grounded wire within the zone of their operations on the pole. This practice, from an operating standpoint is considered undesirable. Moreover the breaking or disconnection of this wire removes all protection.

If the second, or pole-transformer, point for grounding is used, the overhead system is relieved of the hazard just described and the secondary service receives considerable protection, as theoretically any stray current getting onto the circuits will be led to the ground through the grounding wire run from the transformer on the pole to the ground at that point, but this method does not give the greatest protection to the user of electrical energy.

The third and only complete method from the protection standpoint is to ground within the customer's premises, so that the location of the point of protection will be as near as possible to the person subject to the electrical hazard, thus protecting the user from the stray currents occasioned by the crossing of wires from any cause, even though such cross occurs immediately outside of the building served. Such grounds are free from disturbance from any outside cause.

It has been clearly demonstrated that an unreliable ground is most undesirable from a protection standpoint and that a ground of minimum resistance and maximum permanency gives the most complete protection. Therefore, the practice of grounding to active underground water-piping systems affords the most perfect ground connection and by placing such connection immediately within the walls of a building served ahead of any water meters or accessories a protective connection is secured at the point nearest to the user of the electrical energy and at a point which can best be guarded for permanency of the connection.

Several years' experience throughout the United States with thousands of cases of connections as just described proves conclusively that a connection of this nature is in no way harmful to the water-piping systems. It is fortunate that this fact is recognized by nearly all of the water-distributing companies throughout the country, because the continuity of a good ground connection is essential for continued protection, and the locating of the protective connection just within the walls of a building, as described, makes the guarding and inspection of such work easy of accomplishment. This, combined with the desirability of having the ground connection as near as possible to the user of the current, makes this point of grounding the most logical for good results. This is a standard method and is fast becoming the general practice in this country.

The ground wire should be a continuous wire without joints, and of sufficient length to be connected to the service side of the main line fuses. The ground wire should be at least as large as the largest wire used for service mains (except that a wire larger than No. 0000 is not necessary), but in no case should it be less than No. 6 B. & S. gage. When a building is wired in metal conduit, armored cable or metal raceways, the ground wire for such metal installations must never be connected to the ground wire of the secondary circuit.

## Part No. 4.

### INSIDE WORK.

In a former lecture, the intimate relationship of electricity to our industrial life was shown through its application in the form of power by means of the motor. The rules which we will consider this evening, are for a more intimate relationship, even into our home life, as well. We must never lose sight of this fact, electricity used with discretion is the safest form of energy and the rules are for the purpose of maintaining this confidence. We should always bear in mind that householders are not electrically trained, and their attention is distracted from the electrical features by the other activities and processes occurring about them. To the householder, of course, electrical features of his household are mere incidents. For this class of user of electricity, the greatest amount of safeguarding, physical and educational, must be thrown about the electrical wiring and equipment.

This class of rules, however, does not apply to household installations and equipments alone, but contains all of the rules for wiring for light, heat and power as contained within buildings. They do not include the rules for Signaling Systems, such as telephone, telegraph, fire and police alarms, and similar equipments, as these circuits do not present hazards in themselves, being hazardous only from being crossed with light, heat and power wires, or on account of lightning discharges.

The present methods for wiring inside of buildings are the result of experience extending over the period between the earliest applications of electricity to the present time. Methods have changed as the possible dangers were recognized, and as improved means of guarding against them were devised. The net result of this experience has been on the one hand an elaboration of rules and an approach to a few standard systems of construction, and on the other hand the production of an almost endless variety of materials available for electrical purposes.

The earlier installations were laid on timbers under floors, in partitions and over walls without supports, in channels cut for them in wood casings or supported by wood cleats without regard to protecting the wires from injury or the adjacent combustible materials from being ignited by overheated wires, or by arcs. It was the very best type of installation possible at that time. These crude methods, however, have been most wholly abandoned and it is generally conceded that the best protection against electrical fires lies in the adoption of the most approved methods even when the first cost of an installation is increased to some extent.

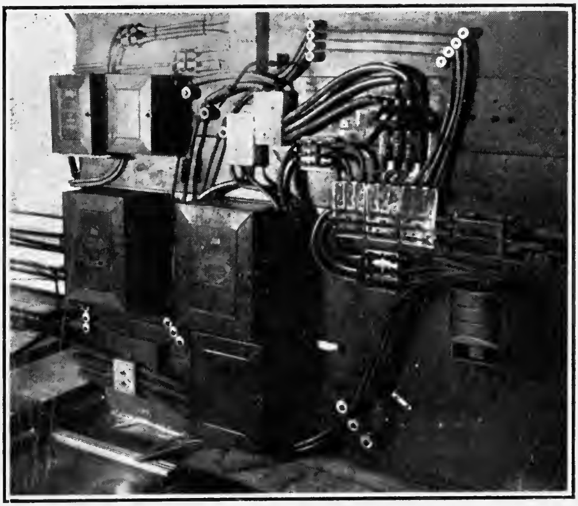
In buildings of the better and larger class, such as our large office buildings, our present day apartment houses, factories, churches and theatres, the electrical installations receive the same degree of careful study and planning as does the general planning of the building and plans are frequently made by electrical engineers acting under the instructions from the architect. The possible efficiency of the installation is most carefully considered, the extent of the equipment, the amount of electrical energy necessary, the method of distribution and the installation of the wires are very completely arranged, that the greatest efficiency and economy may be gained. This economy must not be entirely confounded with the first cost; it applies to the operation of the completed installation. With the smaller installations, we have our greatest difficulty, inasmuch as we do not have this careful planning and supervision, and the wiring oftentimes is an afterthought. Frequently the work is given to the lowest bidder, without regard to his understanding of the problems involved or his method of solving them, and naturally we have cheap construction. However, the general tendency is for an improvement of all electrical installations, and with the supervision which is being given by municipalities and by the underwriters, as a whole, our installations are remarkably safe, and the comparatively few fires at the present time are caused by defective electrical installations.

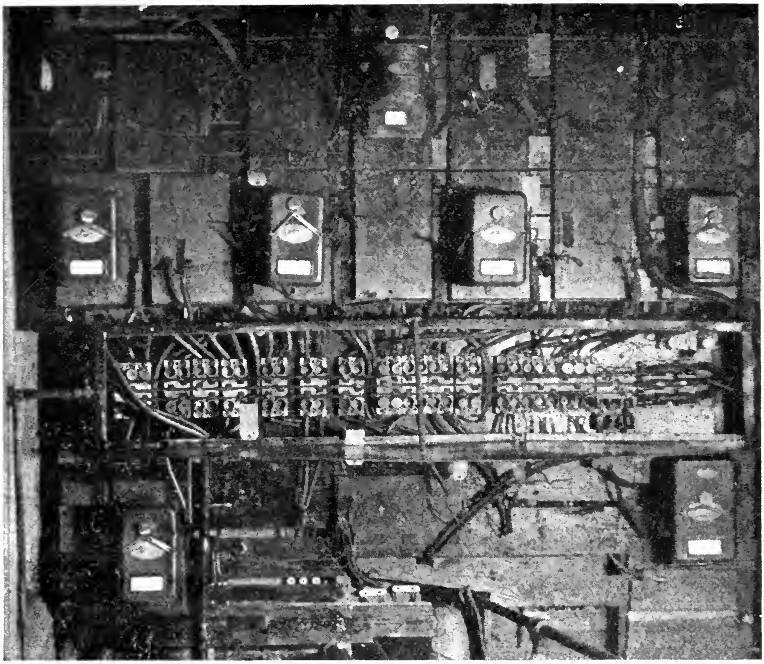
## SERVICES.

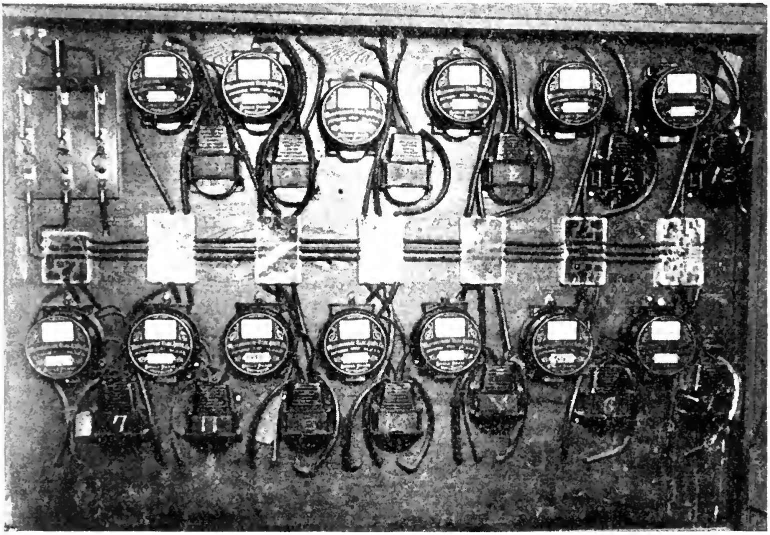
The method of bringing service wires into a building requires care and attention. We have explained the two methods which are most generally used. One, you will recall, was where each wire entered the building through separately bushed holes, and the other was where the low-potential wires entered through a metal conduit, which usually extends into the basement. Rarely do we find high tension wires entering buildings, and when they do, special rules which provide for multiple conductor, lead sheathed cable, installed in unlined metal conduits with the view of protecting the conductors against moisture, are followed.

At the nearest readily accessible place to where the service wires enter the building, must be installed the protection of the system in the form of service fuses and service switch. This switch is usually of the knife blade type and must be so installed that all of the wiring within the building may be entirely disconnected from the outside wires. The service fuses must be placed between the service switch and the outside wires unless the switch is installed in a metal box or cabinet.

The purpose of the service fuses is to protect all of the wiring inside the building from overloads, and should never







Courtesy of Metropolitan Engineering Company.

The three preceding pictures illustrate installation of meters, plug and open link fuses and wires in apartment houses. These installations had a number of hazardous conditions and were typical of the conditions of electrical installations prior to the adoption of the National Electrical Code.

be installed, unless in a dust-tight cabinet, where there are flyings of inflammable materials or so that the molten metal of the "blowing" fuse will ignite combustible and inflammable material.

Service fuses and switches are in several forms, from a pair of small "plug" fuses and "knife" switch mounted on a porcelain or slate base to those of large capacity mounted on a slate or marble switchboard placed in a room specially designed for the purpose, to which the lighting and power mains are connected with separate fuses and switches to control and protect the power and lighting circuits.

## UNDERGROUND CONDUCTORS.

It is practically necessary for underground conductors to enter a building through the foundation wall, in the basement. Where underground service enters building through tubes, the tubes must be tightly closed at outlets with asphaltum or other non-conducting material to prevent gases from entering the building through such channels. It is not desirable to have more than one underground service from a subway to supply more than one building, as it is not advisable to have several buildings fed through one building thus making it necessary to enter the building having the general service in order to cut-off the current in another building.

## GENERAL RULES—ALL VOLTAGES.

No wire smaller than No. 14 B. & S. gage is permitted, except for fixtures and flexible cord. This limitation is not because of the carrying capacity of the wire, but it has been found that wires smaller than No. 14 are not mechanically strong enough to be safely used.

## SPLICES.

We have had your attention drawn to the need of having our joints and splices properly made. While this may seem to be elementary, it is very important. A poorly made splice offers a resistance to the flow of current, which resistance will heat the wire and the heated wire will then inflame the insulation. For general wiring, the underwriters have never found

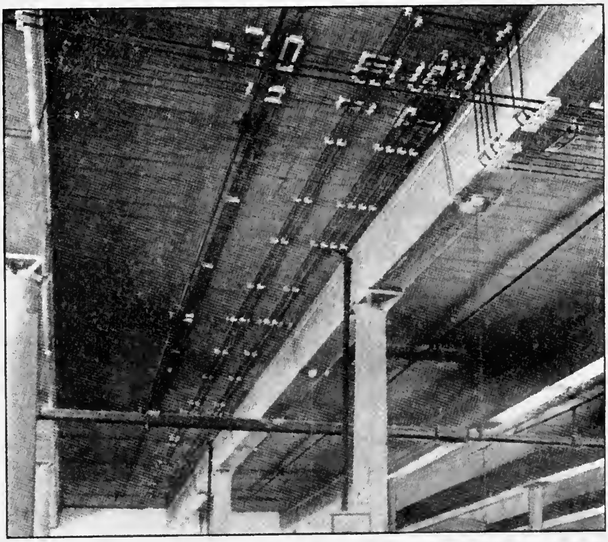

Courtesy Metropolitan Engineering Company.

Installation of cut-out and switches in individual metal cabinets in the cellar of a large apartment house.

the equivalent for good soldered joints when all the possible effects of corrosion, alternate heating and cooling, vibration, and mechanical strains are considered. After soldering, wire joints or splices must be covered with an insulation equal to that at other places on the conductors. This is usually done by winding the splices or joints with a good rubber tape over which is wound a "friction tape" of fabric impregnated with compound.

## WIRES.

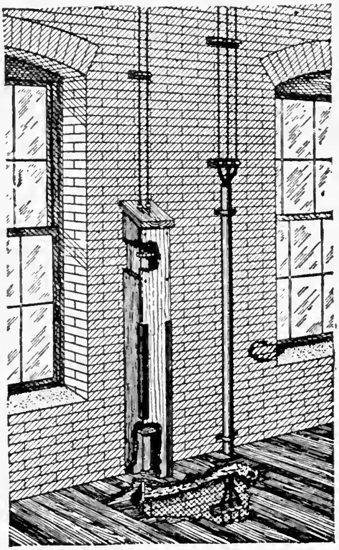
Rubber insulated wire must be used for all concealed work and when installed in damp places or in metal raceways, such as conduits, thin wall conduits and armored cables. For "open work" in dry places where the voltage is not over 550, slow-burning insulation may be used, as it fulfills every requirement for such work, is less expensive and will not carry fire.



A good installation of open wiring; the wires being well supported by cleats and knobs against contact with building and pipes. Wires are also protected against contact with each other through means of porcelain cross-over tubes, which tubes are prevented from sliding along the wires by cleats secured at each end.

When not installed in conduits or other metal raceways, the wires must always be separated from contact with walls, floors, timbers, and partitions by non-combustible, non-absorptive, insulating bushings, such as glass or porcelain, and must be kept free from all contact with pipes or any conducting material. This requirement is without regard to the type or extent of the insulation on the wires, the purpose being that the insulation of the conductors from each other and from other conducting materials must be sufficient to furnish the necessary protection in case the insulation on the wires is defective or becomes injured in any way.

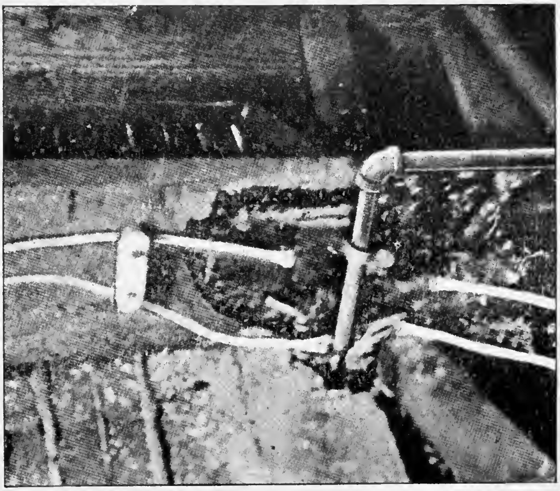
In damp or wet places, the relative arrangement of the pipes and wires should be such that the wires cannot touch the pipes and so that water cannot drop from the pipes on the wires. On this account it is recommended that wires be above rather than below the pipes.



Two methods for protecting wires on side wall against mechanical injury.

## CARRYING CAPACITY.

The Code prescribes the maximum current which shall be carried on copper conductors of the different sizes. These are arranged in table form and are the result of long study and many careful experiments. A reference to this table, which in Rule 18, of the Code, will show that Table A, which applies to wires having rubber insulation, is lower than Table B, which is for wires having insulation other than rubber. This difference is because the rubber insulation will deteriorate under high temperature. These tables, please remember, are to be used for inside work only. It has been stated that for any given size of wire, a current about three times as great as that given in Rule 18, will cause all ordinary insulations to smoke, this being the margin of safety provided, and is none too large considering that often wires must be installed in places having fairly high temperatures, such as boiler rooms, bake houses, drying rooms and lumber kilns. This table of carrying capacity of wires is sometimes confused with the question of drop, some installing wiremen thinking that if they use a wire large enough so as to keep inside of the allowable capacity, as stated in the table, it will be ample, regardless of the distance the circuit is run.

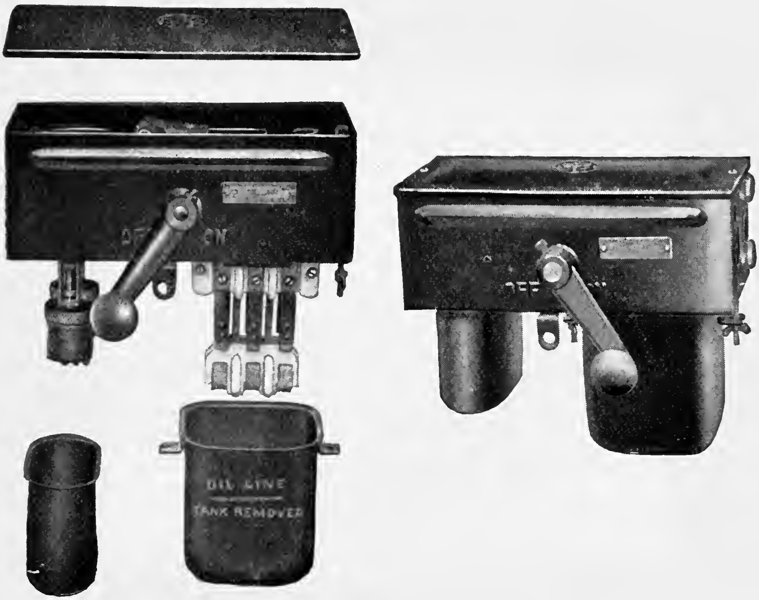


Courtesy Underwriters' Laboratories, Inc.

Fire caused between the ceiling and floor by an arc between the wires for the electric light and a gas pipe.

## DROP.

Since it requires power to keep a current flowing, there must be some power used in keeping the current flowing through the line wires of any system. Of course, all power used in this way is wasted and is therefore, called Line Loss or Drop. As an example, let us consider a dynamo supplying current to a motor, 500 feet away from the dynamo, and we will suppose the motor requires 50 amperes of current at a pressure of 220 volts. From Table A, Rule 18, we find that No. 6 wire could be used. But, as I have stated, some power is lost in driving the current of 50 amperes through the 1,000 feet of line wire and, if the wire is small, its resistance will be large and so more power will be lost on the line wires. So you can see that the part of the dynamo voltage required to drive the working current over the supply wires is called "drop". Suppose, in an installation similar to the one I have endeavored to make clear, it is specified that the drop shall not be over 1 per cent. of the total voltage. One per cent. of




Courtesy of General Electric Company.

An Oil Switch.

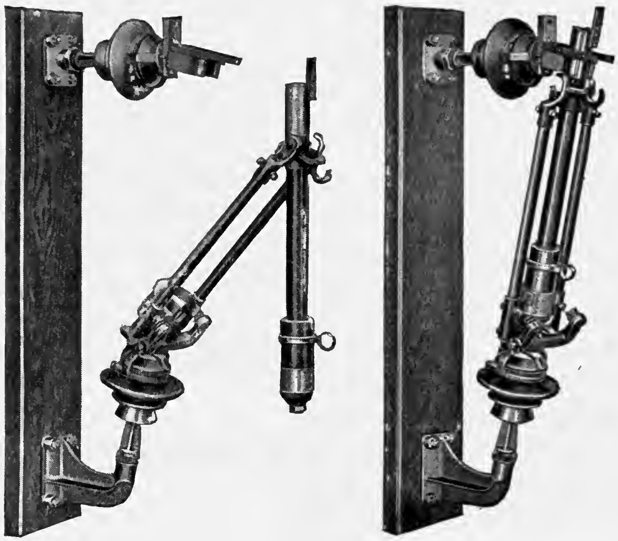
For high-tension work oil switches are used almost exclusively, and in low-tension work they are also extensively used on account of the compactness of construction and the reliability of the operation. The arc being completely enclosed, this switch can be used in places where there is dust or gas. The characteristic features of this type of switch are: knife blade contacts submerged in oil; live parts carried on porcelain base affording a permanent insulation between adjacent poles, and between the frame and live parts; compactness and accessibility; enclosure of all live metal parts. Each contact jaw has attached to it an arcing piece which takes the final break, thus preventing any burning of the jaws. The contact making parts are enclosed in a sheet metal oil tank which has an insulating lining. The above pictures show the oil tank assembled and separated from its supports.

220 volts is 2.2 volts. The current in the line equals the voltage to force the current over the line divided by the ohms resistance of the line.

In this case, $50 = \frac{2.2}{\text{resistance}}$, or the resistance of the 1,000 feet of wire must not be more than $\frac{2.2}{50}$ ohms or .044 ohms. From the wire table of resistance as prepared by the U. S. Bureau of Standards and the American Institute of Electrical Engineers, we find that a No. 0000 wire will be required. Thus the necessity of keeping the loss of power low on the line may necessitate the use of a larger wire than would be needed for safety under the rules. There are cases, of course, where the distance between the dynamo and the load is short and where a smaller wire than that required on account of the heating effect might be used and keep the "drop" within reasonable limits.

## SWITCHES, CUT-OUTS AND CIRCUIT BREAKERS.

Even in the earliest stages of electric wiring, it was evident that some means must be provided for protecting electric conductors, appliances, and machinery from excessive currents and overloads. For this purpose, short lengths of metal conductors having a low fusing point were placed in circuit with the conductor, and were so designed that a slight increase in current above the normal amount would melt the fuse and open the circuit. The practice, to-day, is to use fuses of the plug and cartridge type, and, under some conditions, the open link fuse, which corresponds to the earliest form of fuse. Circuit-breakers, which are automatic in their operation, are used, instead of fuses in installations of the larger size. A fuse and a circuit breaker differ somewhat, in that a fuse is an element designed to melt or dissipate at a predetermined value and is destroyed when its intended function has been performed. A circuit breaker is designed to open a current-carrying circuit, the same as a fuse, but without injury to itself. A circuit breaker may be automatic or manually operated.



Courtesy of General Electric Company.

Expulsion Fuses.

The above pictures represent an expulsion fuse in and out of circuit. In this device there is a short fuse wire mounted between two terminals, one of which is attached to the end of a long lever. When the fuse is blown this terminal is released and a spring acts upon the lever to increase the gap between the terminals to the necessary length to put out the arc.

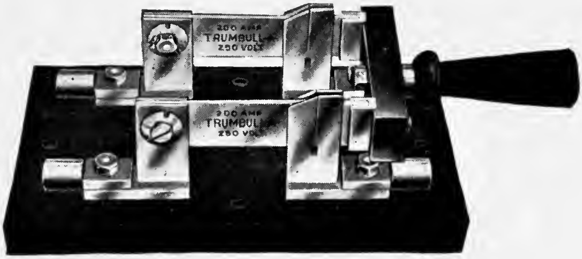
It is quite necessary that switches and cut-outs should never be installed in the vicinity of easily ignitable material or where exposed to inflammable gases or dust of any character, or to the flyings of any combustible materials, such as would be found in cotton mills, wood working plants, flour mills, grain elevators, gas houses, starch making plants, bakeries, etc. In the case of switches, especially of the knife-blade type, when the switch is thrown, there is more or less of an arc, which will ignite flyings of combustible materials or gases. While our present day enclosed fuses should blow without a flash, it is not considered safe to permit them in these locations, owing to the possibility of the fuse "going bad", as it were, when it is called upon to operate through an overload on the system which it protects.

Courtesy of General Electric Company.

A power installation in which the starting device, which is a compensator, is protected by automatic circuit breakers designed for use on alternating current. The above is a good type of installation, all of the wires being in conduit and there being no exposed current carrying parts.

## CONSTANT CURRENT SYSTEMS.

These systems are but little used in buildings to-day, the high-efficiency lamps having almost entirely replaced them. They are in general use, however, for the lighting of our streets. The potential of these circuits range from 2,200 volts to 4,000 volts, and it is, therefore, necessary for such wires to




Courtesy of Trumbull Electric Manufacturing Company.

A two-pole knife switch, which should always be mounted on a slate base.

be well insulated. The present make of arc lamps are enclosed, and therefore there is little danger from sparks of hot carbon falling from the lamps, as was the case a number of years ago, when this method of lighting was so generally used, the lamps at that time being of the open or unprotected type.

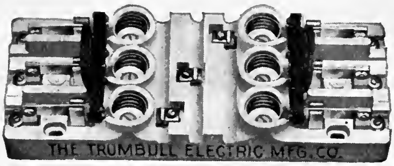
Courtesy of Trumbull Electric Manufacturing Company.

Steel cabinet for the installation of cut-outs.

## CONSTANT POTENTIAL SYSTEMS.

In the Rules we will find the Constant Potential Systems to have been divided into three classes, known as low potential systems, which are of 550 volts or less; high potential systems, which are between 550 volts and 3,500 volts; and extra high potential systems, which are above 3,500 volts.

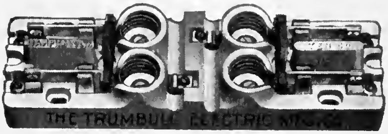
The most common in use for lighting and power are 110 volt two-wire systems, 220 volt three-wire systems, there being 110 volts between the neutral and either of the outside wires. These two systems are used on both direct current and alternating current, although alternating current has very largely replaced the direct current systems. The street railways use a direct current system, with a ground return, which




Courtesy of Trumbull Electric Manufacturing Company.

A combination three-pole plug, double branch cut-out and knife switches. Cut-outs of this type are intended to be used for voltages not greater than 125.

systems range from 500 volts to 600 volts. Most of our power circuits are for 220 and 550 volts alternating current systems, although the use of 2,300 volt alternating current motors is being increased, whereas but a few years ago they were but frequently seen.

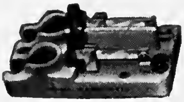


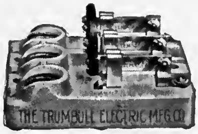

Courtesy of Trumbull Electric Manufacturing Company.

A combination two-pole cut-out and switches, double branch, for use with voltages not greater than 125.

## AUTOMATIC CUT-OUTS.

These are the devices which are intended to protect the circuits and appliances throughout the installation from overloads, and where practicable, should be grouped so as to



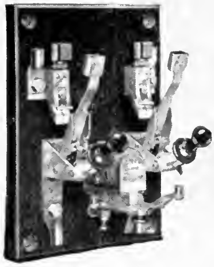



Courtesy of Trumbull Electric Manufacturing Company.

Two and three wire single branch combination cut-out and switch, intended for use on voltages not greater than 125.

make their inspection and maintenance easier, and also on account of usually being able to find a safer location than when they are scattered over a building. It is also better to install the cut-outs in cabinets, so that a "blowing fuse" can cause no trouble, other than disconnecting the circuit.

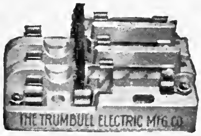
For general wiring, the rules require that no set of small motors, small heating devices or incandescent lamps, nor more than 16 medium size or 25 candelabra size sockets or lamp receptacles requiring more 660 watts, shall ultimately be dependent upon one cut-out. The purpose of this rule is to secure such a subdivision of the fuses that no very large currents can flow for any long time over any part of the small wiring without opening a fuse and thus the effects of a short-circuit, or other accident will be very much minimized.



Courtesy of General Electric Company.

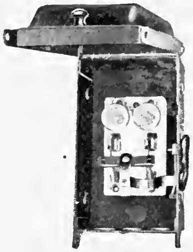
AUTOMATIC CIRCUIT BREAKER.

The above is a circuit breaker intended to be used on a Direct Current circuit. It is a device which automatically opens the circuit, without injury to itself, in event of abnormal conditions in the circuit. In circuits of large capacity a circuit breaker is more desirable than large fuses because of the expense in replacing the latter. A circuit breaker is without the hazards of the fuse, there being no molten metal when it operates.




Courtesy of Trumbull Electric Manufacturing Company.

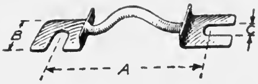
Three pole knife switch, the supply end having terminals for cartridge fuses, which fuses may be used on voltages as great as 250.



Courtesy of Trumbull Electric Manufacturing Company.

Combination two pole knife switch and cut-out, installed in a cast iron box having hinged cover. Generally installed at point where service wires enter the building.

The performance of melting or blowing fuses is extremely variable, their behavior determined by the conditions and surroundings. If there is a slight overload, as sometimes occurs from substituting 60 watt lamps for 40 watt lamps, for example, the temperature of the metal will gradually rise until its melting point is reached, when it will open the circuit quietly. If, on the other hand, a sudden abnormal rise of current is induced, say by a short-circuit, the fuse will tend to disrupt quickly and violently. An important thing to remem-



Courtesy of General Electric Company.

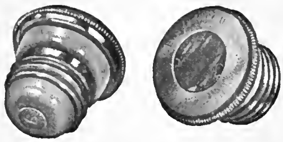
A Link Fuse.

Fuses are the most elementary form for automatically opening circuits under abnormal conditions. They were first made entirely of metals or alloys having a low melting point.

ber is that the carrying capacity of a fuse should never exceed the safe-carrying capacity of the smallest wire made dependent on it for protection. An exception to this rule may be noted for three-wire systems with a grounded neutral. It is felt that with such systems we may omit the fuse in the neutral, or permanently grounded wire, provided both wires of the ultimate branch circuits controlling the lights are properly protected by fuses. When cartridge fuses are used, the capacity in volts and amperes will be found printed on a label pasted on the outside of the tube. With plug fuses, the capacity in amperes will, on 125 volt fuses, be found stamped on the round metal contact in the base of the plug, or on its cover, and on the 220 volt plug fuses printed on a label similar to that used on the cartridge fuses.

Courtesy of Trumbull Electric Manufacturing Company.

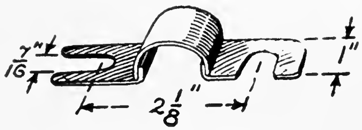
A three pole knife switch with terminals for cartridge fuses of the knife-blade type, installed in a substantial metal cabinet.



Courtesy of General Electric Company.

A PLUG FUSE.

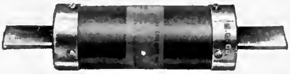
A fuse is an "electrical safety valve", in that it serves to protect a circuit from any harm resulting from an undue overload. Small capacity fuses form an inexpensive means of protecting small circuits. In a plug fuse the element is with the plug and never exceeds thirty amperes capacity. With a very few exceptions lighting circuits should never have larger than ten ampere fuses. Plug fuses should never be used on voltages greater than 125, because of the short distance between terminals.




Courtesy of General Electric Company.

A LINK FUSE.

The simplest form of fuse consists of a strip of metal fixed between two end pieces to fit around the terminals. When a fuse operates the metal melts because of heating and the molten metal will quickly ignite inflammable material. For this reason a "link fuse" should never be permitted except in a dust proof cabinet or on a switchboard in a fire proof room.



Courtesy of General Electric Company.

AN ENCLOSED FUSE.

The enclosed fuses are made up of paper or fiber tubes filled with some material which is fireproof and which seems to suppress the arc formed when the fuse, embedded in this material, opens the circuit. They are made for all capacities, those in use in the mains from the storage batteries in the submarines of the United States Navy being for 2,300 amperes. Because of the action of the powder, in suppressing the arc, these fuses were first called "non-arcing fuses".

Courtesy of General Electric Company.

AN ENCLOSED OR CARTRIDGE FUSE.

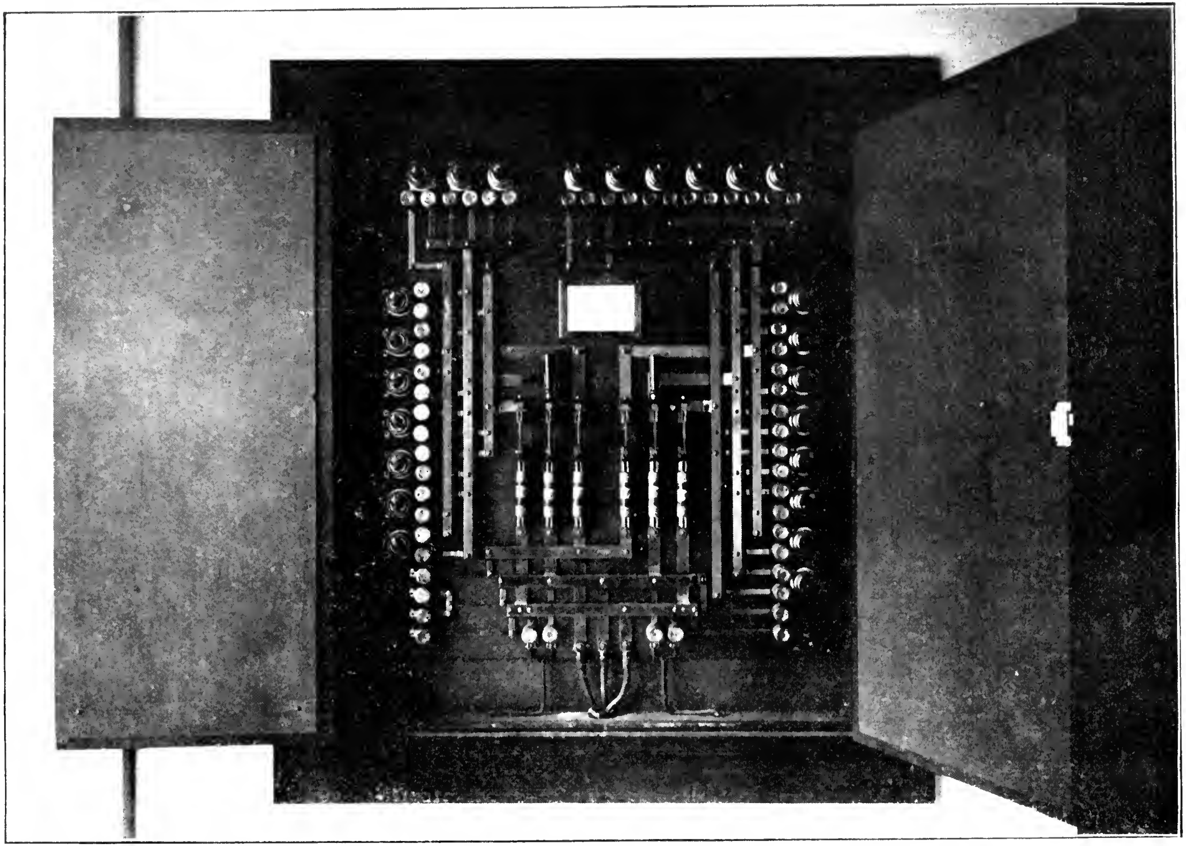
The above illustrates an enclosed or cartridge type of fuse, in which the space surrounding the fuse wire is filled with powdered material. Because of the distance between the terminals this type of fuse may be used on all commercial voltages without danger of arcing when the fuse operates.

## SWITCHES.

Service switches are generally of the knife-blade type, and are mounted on either porcelain, slate or marble bases. They must be so installed that current may be entirely cut off from the inside wires for repairs, or in case of fire, or other accident. A single-throw switch is one having one set of contacts, a double-throw being where there are two sets of contacts. Single-throw switches must always be installed so that gravity will tend to open rather than close them since otherwise they might fall and, by only partly closing, cause arcs and burning. Whenever practicable, knife switches should be so wired that the blades will be dead when the switch is open. Switches for the control of motors, and where the current used is in excess of 20 amperes, are usually of the knife-blade type.

Surface Snap Switches are those which are in most common use and generally have a round porcelain base, with a metal cover and an operating handle in the center of the cover. In use, they are generally mounted on side walls and the wires are brought into them from the back. It is not possible to fasten them securely to a lath-and-plaster wall unless some block is provided for the screws to be driven into. For this reason a ⅞" block must be fastened between the studs flush with the back of lathing to hold tubes, and to support switches and fixtures, as the case may be. When this cannot be done, wood base blocks, not less than ¾" in thickness, securely screwed to lathing, must be provided for switches, and also for fixtures which are not attached to gas pipes, conduit, or other form of support. The switches can thus be securely and firmly screwed to the blocks and the wires connected to them. When the switch wires are run exposed, the snap switches should be mounted out from the wall on porcelain sub-bases, so that the wires may enter the switch from the back without coming in contact with the wall on which the switch is mounted.

Flush switches are of the type which are inserted in the wall, only the face plate, with its handle or buttons, showing. That is why they are called flush switches. Inasmuch as their operating parts are concealed in the wall, they should always be set in enclosed iron boxes, so, should the switch go wrong and arc, no flash or flame can extend outside of the metal enclosure. The same general requirement applies to all small



Courtesy of Commissioner James E. Cole, Wire Department, Boston, Mass.

Panel-board upon which are mounted snap-switches, knife switches, plug and cartridge fuses, also copper bus-bars. This panel-board which is enclosed in a steel cabinet, is in the Harvard Medical School, Boston. Plug fuses having a short distance between terminals are intended for voltages not greater than 125. If used on voltages greater than this fittings, such as receptacles, there being the handy devices into which an attachment plug, with a flexible cord connected to it, is inserted for the use of a table lamp, fan motor, small cooking utensils and similar appliances.

Courtesy of Trumbull Electric Manufacturing Company.

Three pole knife switch and cut-out installed in a metal cabinet, the door of which is so arranged that the switch cannot be closed when the door is open.

Sometimes it is desired to control the same lights from different places, as in the case of hall lights being controlled from two or more floors. This is a practical thing to do by the use of three and four way switches. These switches are always to be considered as single pole and are to be so connected that only one main wire of the circuit feed is carried into either switch. These switches, as I have indicated, being single pole, should never be used on circuits of more than 660 watts.

## ELECTRIC HEATERS.

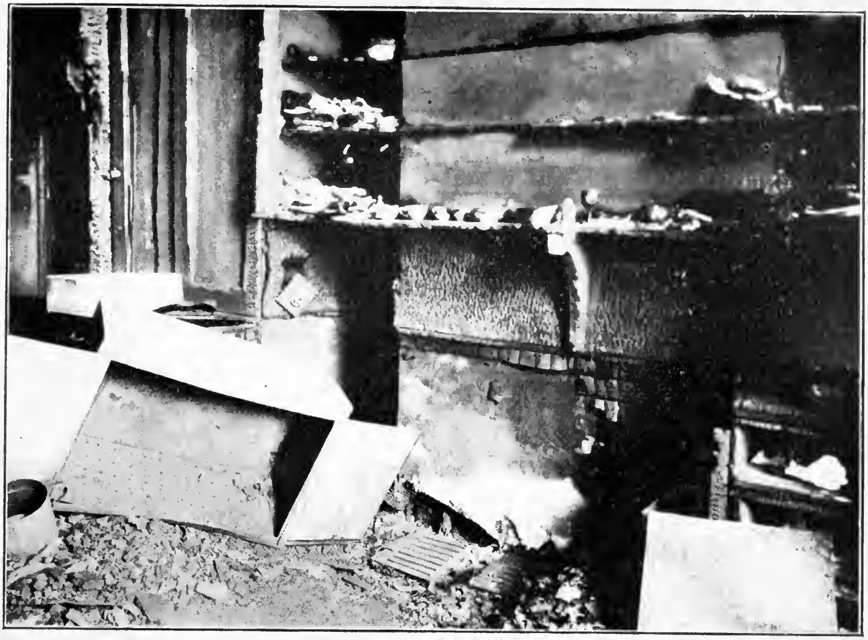
Under this heading are included all devices in which use is made of heat developed by the current, usually by causing it to pass through coils of wire. Perhaps it may be said, with some force of truth, that this branch of the application of electricity has developed more forms of practical applications, in the last few years, than all of the other branches. These electric heating devices are in many forms, from the household chafing dish to the large broilers and ranges in the grill rooms of the modern hotel. A few years ago, I ate my meals in a restaurant, in the small town of Houlton, Aroostook County, Maine, in which everything served had been cooked by electricity. We have curling irons, which of course I do not use, for reasons which are obvious; pads to take the place of hot water bottles, which are without the danger of bursting and thus spilling the hot water on the patient; radiators in several forms; radiant grills; toasters, percolators, egg codlers, hot water heaters, flatirons and an almost endless variety of devices, all of which present the same hazards as other heaters of equal capacity, except that the match hazard or the explosion hazard, where gas is used for cooking and heating, are eliminated.

It is essential that these devices be protected by fuses in the branch supply circuits and also be controlled by switches which will indicate whether or not the current is "on" or "off." They should never be concealed without special permission, and when concealed should be arranged in such a manner that the heater could burn up without damage to surrounding objects.

Experience has shown the fire underwriting interests that the portable heating devices are much more hazardous than

Courtesy of Commissioner James E. Cole, Wire Dept., Boston, Mass.

Dining room in a residence in Boston, Mass.



Courtesy of Commissioner James E. Cole, Wire Dept., Boston, Mass.

Butler's pantry in same residence.
Fire caused by defective installation of electric plate warmer, with a total fire insurance loss of $180,198.06.

those of the stationary type. This is not because of a possible defective installation, since the stationary heaters may be suitable protected, while it is not always possible with those of the portable type. The electric flatiron is perhaps the cause of more trouble and danger from fire than any other form of heater, a fact due entirely to use and management rather than to installation difficulties. The temperature of the iron required for ironing of damp fabrics is necessarily high and if the iron is left with current on and is not in use it will become red-hot in from ten to twenty minutes. If it is left on a table or on clothing, a fire is to be expected.

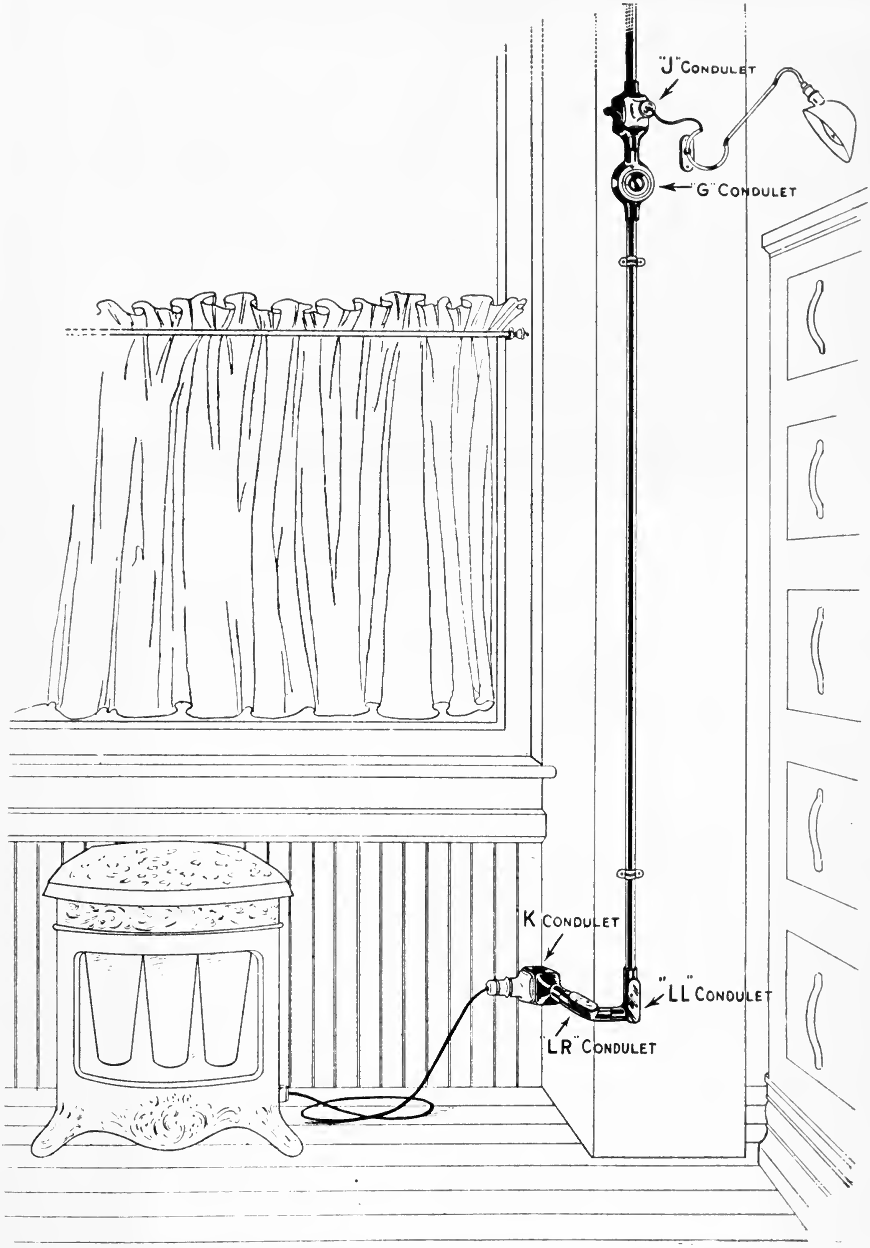
All portable heaters, if they require over 250 watts of energy should have approved "heater cord" which consists of stranded copper conductors with a thin rubber and a thick asbestos yarn covering over each, with good braid over all. In factories, shops, clothing manufactories and manual training schools, where a large number of flatirons and other portable heaters are used, the circuits supplying them should be so arranged with switches that any department or section can be cut-off when not in use.

Unless flatirons are small, they should not be used on the ordinary lighting circuits, as they would overload such circuits and cause heating of the smallest wire on the circuit,


Courtesy of Crouse-Hinds Company.

Method suggested for the installation of an electric flatiron, the fitting having a snap switch and fuses for the protection of the flexible cord and flatiron. Within this fitting will be seen the tell-tale lamp, the glow of which indicates whether or no current is flowing through the iron.

which wire is in the lighting fixtures. The lighting fixtures and sockets are not substantially enough constructed to permit of the rough usage which they will receive if these devices are connected to them. Electric flatirons should, in all instances, be provided with approved stands to receive the irons when not in use.




Courtesy of Crouse-Hinds Company.

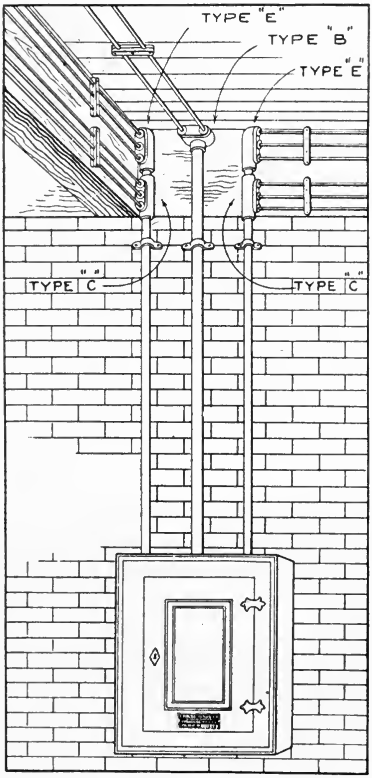
A luminous radiator connected to circuit wires in conduit by the means of flexible cords, an attachment plug and receptacle, the latter secured to a receptacle fitting. Heating devices of this type should be kept well away from the woodwork of the room.

## METHODS OF WIRING.

Various methods have been standardized for the installing of wires for low potential systems, which at the present time includes all systems of 550 volts, or less. We shall consider these methods separately.

OPEN WORK:—This method of wiring is used very extensively on ceilings in mills, factories, stores, and for heavy conductors for feeders, mains, etc., in tunnels and in similar places. Where the appearance of exposed wiring is not objectionable, this is one of the safest, cheapest, and best methods of wiring. In fact, if properly done, its appearance is far from objectionable.

In dry places, up to 300 volts, it is permitted to support the wires on porcelain cleats which raise the wires ½ inch

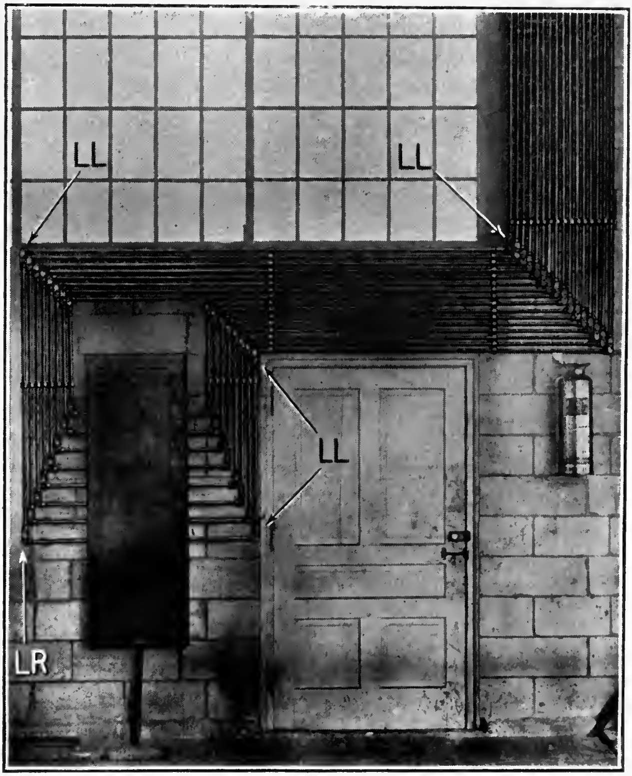



Courtesy of Crouse-Hinds Company.

Open wiring entering conduits through terminal fittings, which have a separately insulated opening for each wire.

from the surface wired over, the wires being 2½ inches apart, and for voltages between 300 and 550 the distance is to be one inch, the wires being kept four inches apart. The distance between supports should not be greater than 4½ feet, and if the wires are liable to be disturbed, this distance should be decreased. For such work, the so called slow-burning insulation may be used. In damp places, wire having a rubber insulation must be used and the supports must raise the wires at least one inch from the surface wired over, the wires to be kept 2½ inches apart in systems up to 300 volts, and four inches apart for systems between 300 and 550 volts. The distance between supports to be such as will prevent the wires being disturbed, but never less than 4½ feet.

MOULDING WORK:—Moulding is now called "race-




Courtesy of Crouse-Hinds Company.

A well arranged conduit installation from a distributing cabinet to the various outlets. The use of the peculiar fittings make possible the absence of long bends, thus keeping the conduits close to each other.

ways" and is sometimes used where the use of cleat work would be objectionable from the standpoint of appearance, and where it would be impracticable, difficult or expensive to install concealed wiring. Raceways, either wood or metal, should never be installed in a damp place nor should they be concealed. Wire having a rubber insulation must be used and splices in the wire should not be made. Where taps or extensions of wire are necessary, fittings for this purpose should be used. In metal raceways, single circuits should be limited to 1,320 watts and the several lengths of the raceways should be electrically bonded and effectively and permanently grounded.

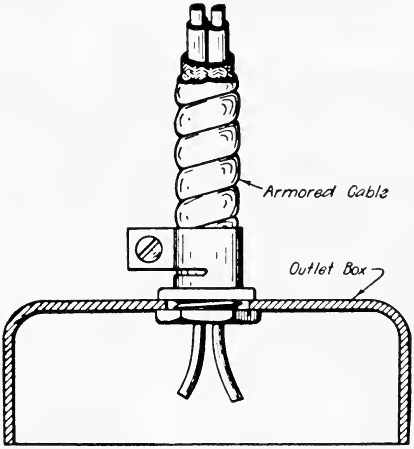
CONDUIT WORK:—The requirements of a good conduit are first, it should be fire-proof. There exists in every electric conduit for light or power the elements necessary to cause fire, and every precaution should be taken to prevent the conduit from igniting and burning. In the second place, it should be moisture proof, while, in the third place, the conduit should be strong mechanically. It should resist nails,


Courtesy of Crouse-Hinds Company.

Installation of conduits with special fittings for electric flatirons in a tannery.

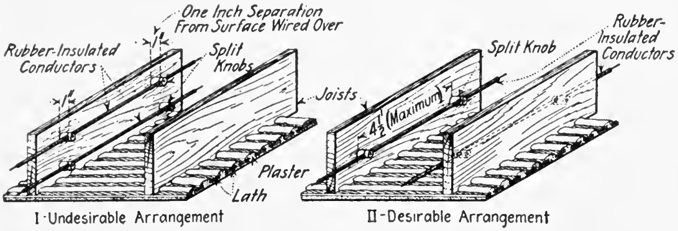
hard blows, and should not easily be flattened by being walked upon or by having wheelbarrows run over it. Lastly, the conduit should withstand a "short-circuit" on the wires which they contain without disrupting. Wires having a rubber insulation should be used in conduits and the conduit system should be grounded.

ARMORED CABLES:—As the name implies, this method consists of the wires being protected by a flexible steel armor which is wound over the rubber insulated wires. It is much more convenient to install, for concealed wiring, than rigid conduit, to which it is inferior in one respect, since the wires cannot be withdrawn should it be advisable to do so. As in conduit, the armored cable systems should be grounded.

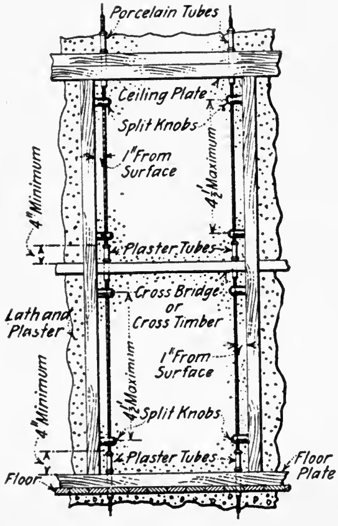



Customary way of fastening flexible steel-armored cable in junction or outlet box.

CONCEALED KNOB AND TUBE WORK:—This method of wiring is used where first cost is of the greatest importance. In this method, the wires are run concealed under floors and in partitions supported on porcelain knobs and insulated where they pass through floors and beams by porcelain tubes. The knobs are used where the conductors run parallel to the joists and for vertical runs, and the tubes are used where the wires pass through the joists and plates or heads of partitions. Flexible tubing is used at outlets to protect the wires. Here again rubber insulation is required and the wires are to be supported on knobs which raise the wires one inch from the surface wired over, the supports being not greater than 4½ feet apart. While this method may be open to objections, mechanical injury by artisans installing their own work or making repairs, it is reasonably safe, and does tend to drive out the match hazard. It is much safer than kerosene or gas which it replaces.



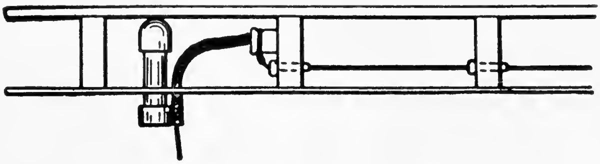

FIXTURE WIRING:—Fixtures should be wired with rubber insulated wire, except where the lighting units develop excessive high temperatures, and should be insulated from the gas piping and other grounded metal work of the building. Under some conditions fixtures may be installed without insulating from the grounded metal parts of the building, providing the insulation of the fixture wire is the same as that of the circuit wires and specially designed sockets are used. The ordinary wire cannot be used in the average lighting




**Showing Application of "Plaster or Mud Tubes."**

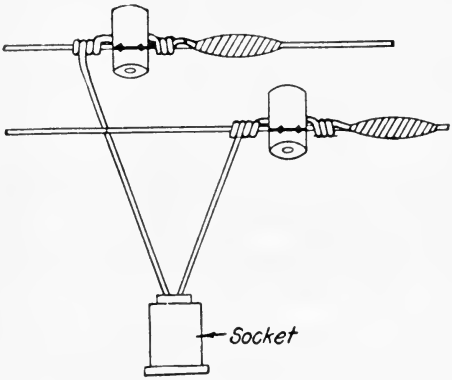
fixture because of the thickness of its insulation, so a wire having a thinner insulation is permitted.

SOCKETS:—Sockets used in stables or other damp places, should, preferably be of the porcelain type. The ordinary key socket should be considered as a single-pole switch and should never be installed where there are inflammable gases or vapors which could be ignited by the spark when turning off the current by the key, or switch, in the socket. In such cases, the lamp should be in a vapor proof globe as a protection to the lamp and a keyless socket used, such socket to be controlled by a switch which must be located beyond reach of the gases and vapors.



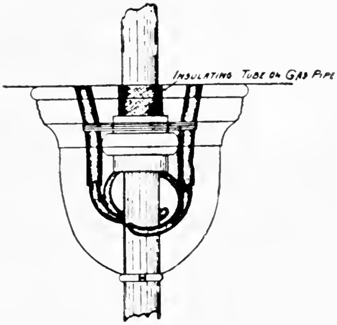
FLEXIBLE TUBING ON OUTLET WIRES.

FLEXIBLE CORD:—The proper and intended use of flexible cord connected with electrical installations has been of very great value in aiding the application of electricity and nothing has caused as much harm as through its misuse. The ordinary flexible cord consisting of two stranded conductors, each conductor insulated with rubber and surrounded with a cotton or silk braid, is intended to be used, other than in a fixture, on devices which hang freely pendant in the air. It




Method of installing short pendent in damp location.

should never be run over ceilings, down sidewalls or partitions, or through the floors. Nor should it be used for portable devices nor in show windows. For portable purposes a flexible cord similar to the one I have described, but surrounded by a tough braided outer covering, should be used that the conductors may be protected from the mechanical abuse which frequently results. Flexible cords should never be used in damp places, nor should they be hung on nails, metal work or stapled to wood work. Adjusting devices that tend to destroy the insulation of the flexible cord should not be used.

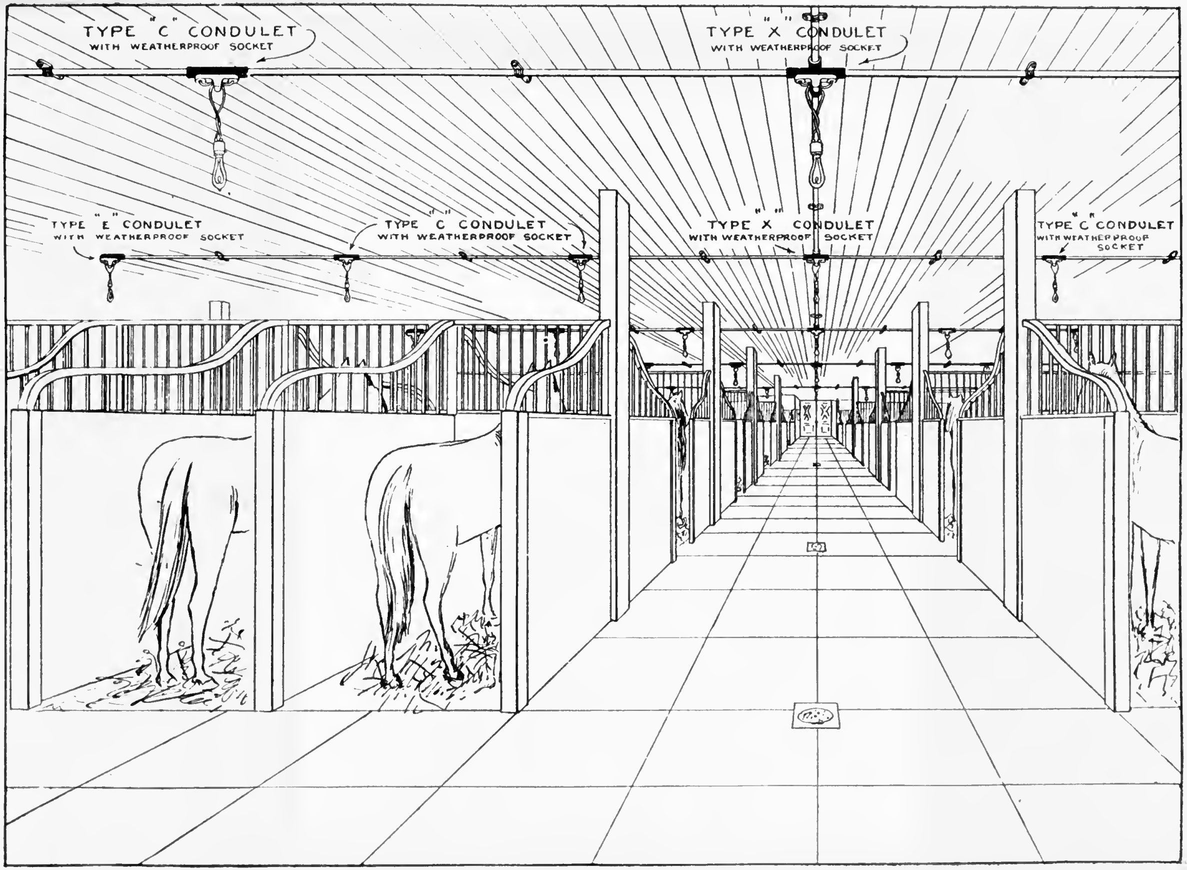



Method of installing a lighting fixture on a gas pipe, showing the protection of the circuit wires with flexible tubing, the insulating joint and the insulating tubing on the gas pipe above the joint.

ARC LAMPS, LOW POTENTIAL CIRCUITS:—The progress made in the high-efficiency incandescent lamp has made the arc lamp almost unnecessary for interior lighting. When, however, arc lamps are to be used, common practice provides for these lamps to be supplied from the ordinary 110 or 220 volts circuit. They should be considered the same as if supplied by series circuits, it being necessary to provide them with globes, spark arrestors and wire netting.

## Part No. 5.

In our preceding lectures, an effort was made to point out electrical hazards which might be found in most any type of installation. This evening, we will endeavor to make clear hazards which can be found in such installations having special features of use, materials and appliances.

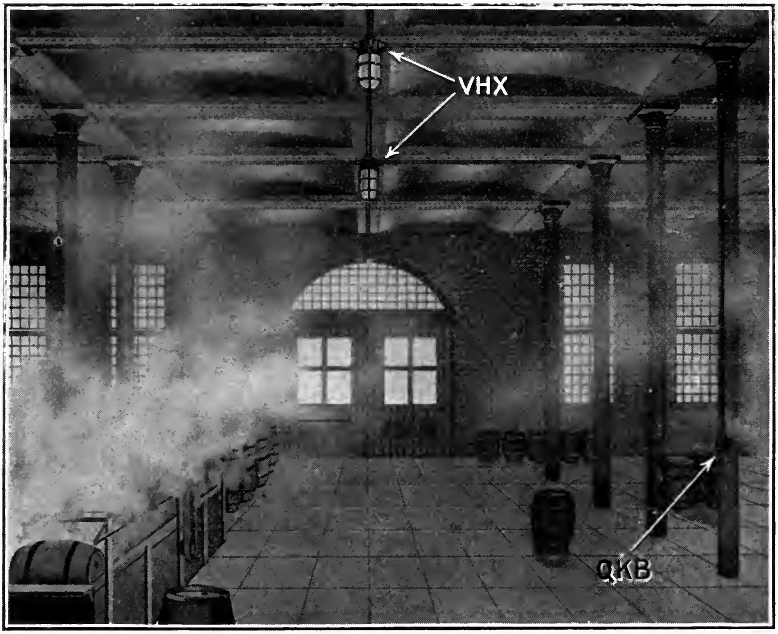



Courtesy of Crouse-Hinds Company.

Metal shell sockets should not be used in the stall rooms of stables. The above installation complies with the requirements in that the sockets are of the weather proof type and the caps of the fittings being of porcelain.

## VAPOR LAMPS.

An enclosed mercury vapor lamp consists essentially of two separate elements, the tube or light-giving part, and the operating mechanism. The tube is of clear glass of varying length, from 21 inches to 55 inches, with electrodes at each end and containing a small quantity of metallic mercury. The air is exhausted and the tube then sealed. The mercury is held in the large bulb at one end of the tube, and serves as the negative electrode, the tube being always so suspended that this bulb is the lowest part of the tube. The positive




Courtesy of Crouse-Hinds Company.

Installation of electric lights in a location where inflammable gases are present, the lamps being located in vapor proof globes.

electrode is a small iron cup at the other end of the tube. The current is conveyed to the electrodes through platinum wires sealed in the glass. The current, passing from the positive electrode to the negative, vaporizes some of the mercury and causes the vapor to become luminous. That these lamps, which are essentially intended to be used on direct-current systems, may be used on alternating-current systems, an auto transformer is used. The quality of the light is peculiar, it containing no red rays and has a peculiar bluish-green color.

The auto-transformer and resistance used with these lamps should be treated as possible sources of heat and must always be enclosed in non-combustible cases and must have all openings in their casings covered with fine wire gauze when installed in locations where there are flyings of lint or other combustible materials.

## HIGH POTENTIAL VACUUM TUBE SYSTEMS.

While this form of lighting is not in general use, the Code has made provision to safeguard the several hazards involved. In theory it is similar to the Geissler tube and resembles the mercury vapor lamp in that it consists of a conducting vapor enclosed in a tube and owes its illuminosity to the incandescent particles of matter in the vapor stream. These tubes vary in length from 40 to 200 feet of continuous glass tubing. The conducting gas is supplied to this tube-nitrogen, emitting a yellow light, gives the highest efficiency, while carbon dioxide gives a white light differing little from daylight. When the tube is fed with air alone, the light is a pale pink color.

The terminals of the tube are brought to a terminal box and sealed upon carbon electrodes which serve the purpose of conducting the electricity to the gas. This terminal box contains a step-up transformer with its high side connected to the tube, and a regulating device to control the density of the vapor in the tube. This glass tube must be so installed as to be free from mechanical injury or liability to contact with inflammable materials. The high potential coils and regulating apparatus must be installed in a steel cabinet not less than $1/10$ inch in thickness; same to be well ventilated in such a manner as to prevent the escape of any flame or sparks, in case of burnout in the various coils. To protect against dangerous shocks, any openings in the box near the high-voltage parts should be effectively screened or protected by other suitable means.

## GAS FILLED INCANDESCENT LAMPS.

This is the highest development of the incandescent electric lamp. Nitrogen or Argon gas is used in the bulbs which greatly increases the illuminating power of the lamp and decreases the consumption of energy. In the old carbon filament lamp, 3½ watts of energy were required for each candle-power the lamp gave. The old commercial unit, the 16 candle-power lamp required 55 watts of energy, whereas, the so-called gas-filled lamp, in some instances, requires but ½ watt for each candle-power. To achieve this result, a hazard was introduced in the intense heat which is given off by these lamps. They must never be used in a show window or in other localities where inflammable material is liable to come in contact with the lamp equipment except when used in connection with approved fixtures where the temperature of any exposed portion of same does not exceed 200 degrees Fahr. If the lamp is above 200 watts normal capacity, it must never be used in the medium based sockets or receptacles. If above 100 watts, must not, if provided with a shade, reflector, fixture or other enclosure above the socket, be used in either medium or Mogul base types of sockets or receptacles having fibre or paper linings. When the temperature from these lamps exceeds 120 degrees Fahr., the fixtures within buildings must be wired with conductors of approved slow-burning or asbestos covering. Where fixtures are placed outside of buildings, approved rubber insulated wires is required.

## OIL TRANSFORMERS.

Must not be placed inside of any building, except central and sub-stations, unless by special permission, and only then when they are installed in fire-proof vaults, as described in a preceding lecture.

## TRANSFORMERS, AIR COOLED. INSIDE USE.

There are several types of air-cooled transformers which are permitted within buildings because of their low capacity ratings. Some electric lighting companies have a low-potential contract system in which no recording watt meter is used. A special potential, however, is desired that the consumer may not use more current than has been contracted for. That the desired potential or voltage may be obtained, an air-cooled transformer, called an auto-transformer, is installed within the building, stepping the potential down from 110 volts to

55 volts and sometimes to 27 volts. These transformers must always be considered as possible sources of heat and should be enclosed in iron cases. They must, also, be mounted on slate or marble bases and should never be installed in closets where there will be combustible and inflammable materials.

Electrical transformers for stepping down alternating currents of the usual lighting circuit to a much lower potential for operating electric toys and the ringing of the ordinary house bells are in general use. It can be said that small electrical devices used on a few volts may have no limitations as to cheapness. But it is quite otherwise with the toy transformer that is connected to the 110 volt circuit. It is of the utmost importance that toy transformers be made as fool-proof as possible. They must never be connected to systems of greater than 125 volts, nor should the low-voltage rating exceed 25 volts. The input measured by a watt meter in the high voltage side, when the low-voltage terminals are short-circuited, must not be more than 25 watts.

## DECORATIVE LIGHTING SYSTEMS.

Decorative lighting by means of incandescent lamps is often desired either inside or outside buildings. The chief hazards of such work lie in the use of inferior materials hastily put together and poorly located and fused. The voltage of such systems should never exceed 150 volts and not more than 1,320 watts of energy should ever be permitted to be dependent upon a single cut-out. It would be improper to take current for such systems from ordinary outlets, since by so doing, the wires to the outlets would be overloaded and the proper fuses for the wires will have to be replaced by others of too great capacity to furnish safe protection. The supply should be taken only from points on the circuit where the correct fusing and wiring can be provided for.

The wires are often made to serve as supports for merchandise of very inflammable material and the conditions are excellent for a rapidly spreading fire if any electrical failure should occur. Incandescent lamps frequently lie against inflammable material and the fact that such an installation is "temporary" does not lessen the hazards as long as it is in operation and should not in any sense be considered as an excuse for allowing practices which are known to be dangerous.

## ELECTRICALLY OPERATED ORGANS.

There is an electrical fire hazard in those parts of electrically operated organs which are employed for the control of the sounding apparatus, such as the reeds, pipes, drums, etc., and the keyboards on the consols. The electrical energy may be from a battery or a self-excited generator rated at not over 15 volts. The conductors, which may be bunched in a cable, must have either rubber, cotton or silk insulation. When in cable form, unless installed in conduit, the outside covering must either be flameproof or covered with a closely wound fireproof tape. The circuits must be so subdivided and protected at the generator by approved enclosed fuses of not over thirty amperes capacity that every wire will be protected by one or more such fuses. By such fusing at the required 15 volts, each circuit would then be limited to 450 watts.

## THEATRES AND MOTION PICTURE ESTABLISHMENTS.

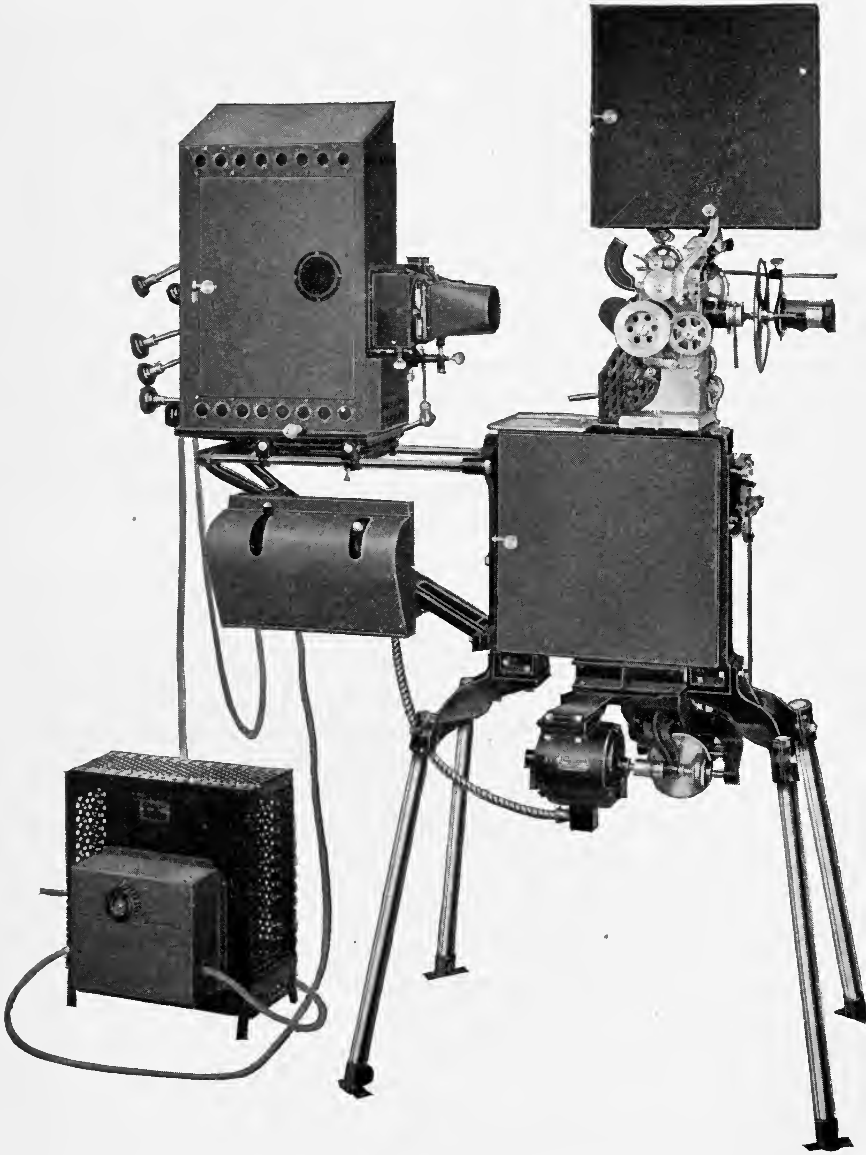
These risks, with their electrical installations, require careful attention because of the fire and life hazards involved, the latter being of the greatest importance. In the fully equipped theatre, we have not alone the fire hazard from electrical causes, but the hazards of scenery, dressing rooms, paraphernalia and the numerous devices for producing stage effects. What are termed moving picture establishments, in many instances, are without the dressing rooms, scenery and the other hazards of a theatre, but have a hazard. while not electrical, of the greatest concern. These moving picture enterprises have often been established in rooms originally intended for stores and the equipment has been of the poorest character. This condition has been greatly improved as experience has been gained and has been made the subject of legislation by state, municipal and insurance interests. The requirements for the electrical equipments in both of these amusement enterprises are the same. In brief, they provide for the following:

FIRST:—There shall be two services of supply for the lighting of the building, one to care for the equipment on the stage and the general lighting for the auditorium; the other service, which must be entirely independent of the service for the general equipment, for the supply for the emergency or exit lights. This provision bears but little upon the fire hazard, but is intended to provide illumination sufficient for the audience to pass from the building under any and all conditions liable to exist, even when the general illuminating system has been rendered useless. This would aid in preventing a panic.

SECOND:—The wiring on the stage and the concealed wiring in the building must be in metal conduits or armored cables. Should, however, any of the wiring be exposed in the auditorium, stairways or lobbies, such wiring may be in conduit, armored cables or metal raceways. All of the stage equipment, as well as the house lighting, except the emergency or exit lights, are controlled from a switchboard located on the stage. If the switchboard is on the level of the stage, a railing is required across the front of the switchboard to prevent performers coming in contact with the exposed live parts of the equipment. The dimmers, footlights, borders and all equipment are designed and installed with the view of preventing contact with scenery or injury through the regular use of the equipment. The proper installation of all the stage devices, many of which are used for special effects, is such an important feature of the safety of the theatre that special rules are established for portable conductors for lights on scenery, for festoons, and for many special effects.

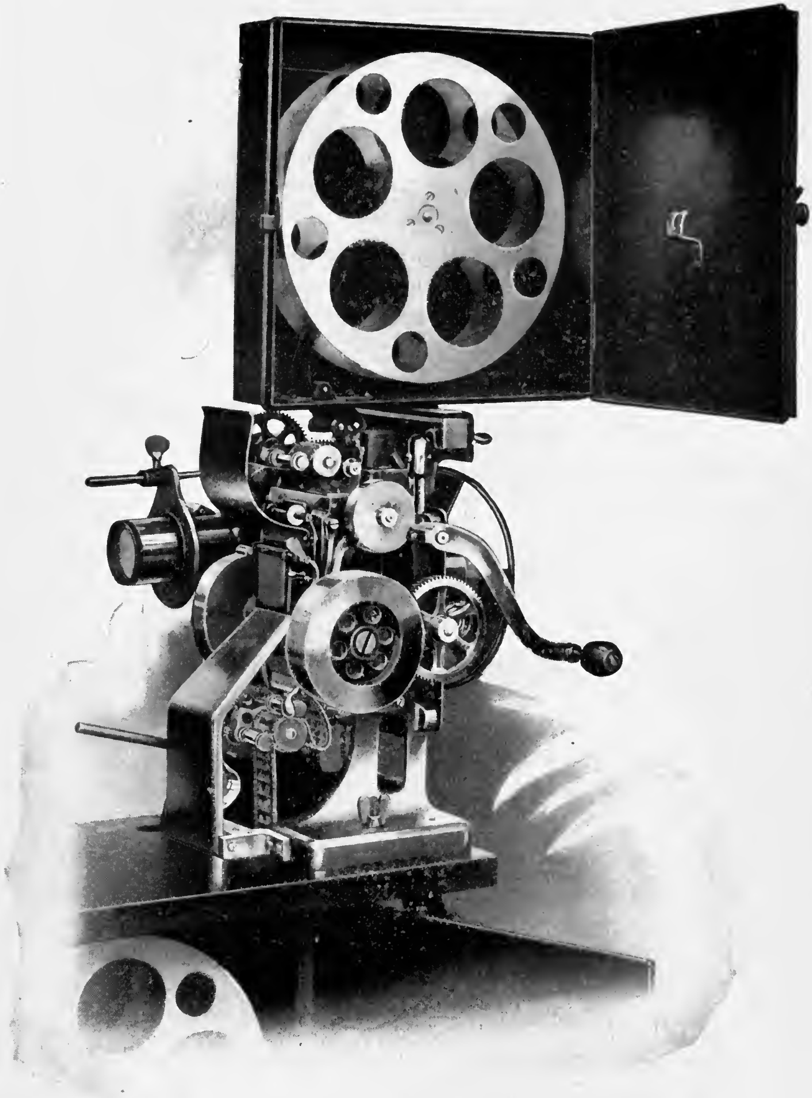
## MOTION PICTURE MACHINES.

The motion picture machines in use to-day represent the combined experience of a number of efforts and are to be found in use in most of the theatres for entertainment and in a number of our institutions of learning for educational and scientific purposes. It might be described as an intricate stereopticon having an arc light in a metal housing, as an illuminant. It does not, as many suppose, reproduce photographs of motion but does show a number of separate and distinct pictures, but the speed with which these pictures are shown upon the screen deceives the eye and they appear as if in actual motion, rather than separate pictures with even the light being withdrawn from the screen, between the pictures, for a small fraction of time. This deception, or optical delusion, is accomplished by a revolving shutter by which the light on the screen is cut off during the movement of the film and consists of three wings, one of which is rela-



Courtesy of Nicholas Power Company.

Power's Cameragraph No. 6B with motor drive. This machine represents the progress made in this science.



Courtesy of Nicholas Power Company.

Mechanism showing the automatic shutter, film shields, drive crank and film of Power's No. 6 Cameragraph.

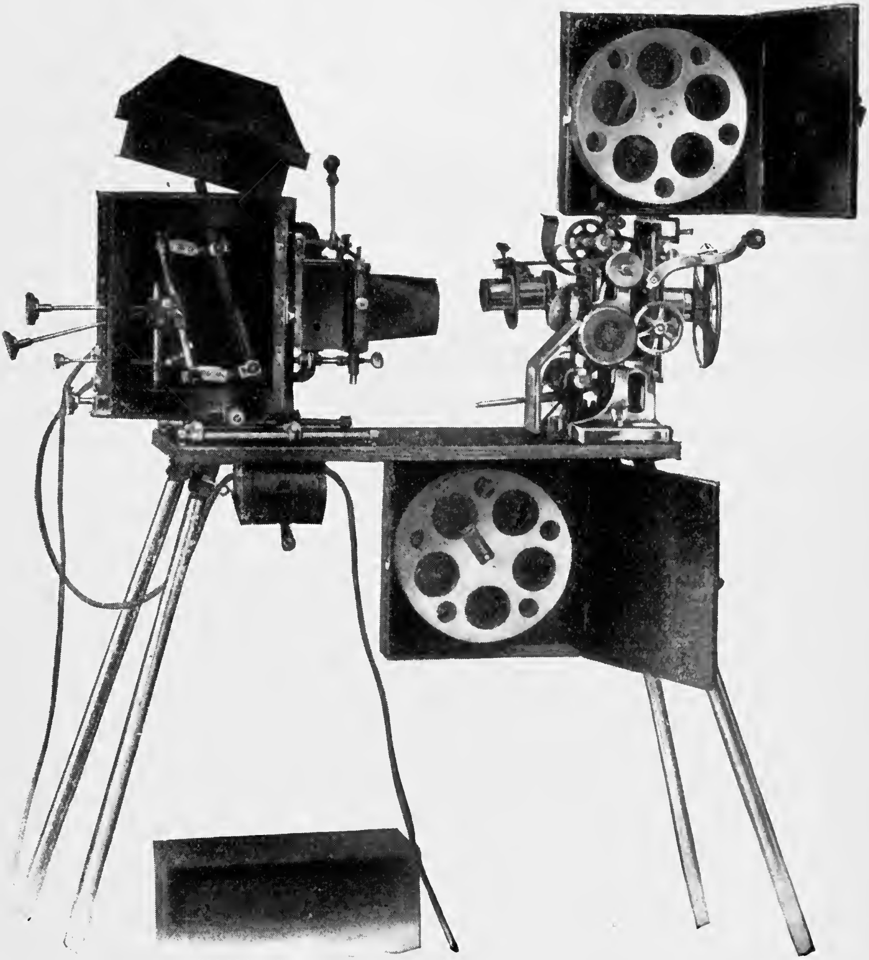
tively wide and obstructs the light on the screen during the movement of the film, the other two relatively narrow and adapted to interrupt the light twice while the picture is on the screen, so as to prevent flicker. The pictures on the film must be in absolute synchronism with this shutter. This is accomplished by sprocket wheels over which the film passes from the upper magazine through the head of the machine to the gate, or aperture, through which the condensed light rays strike the film. The film continues over other sprockets to the lower magazine. The magazines, sprockets, revolving shutter and gate at the aperture are all connected by gears and belts to the source of power which is generally a small motor.

The hazard is in the film which is made of Nitro-Cellulose and is extremely inflammable, igniting without contact with a flame at about 210 degrees Fahr. These films are on metal reels and are from 500 feet to 2000 feet in length. The commercial film is 1-$^{11}/_{32}$ inches wide having perforations on both sides, such perforations corresponding to the sprocket wheels, which have 5.4 teeth to an inch. There are 16 pictures on 1 foot of film. These films should always be kept in metal cases having tight fitting covers and should never be exposed or operated unless in a booth constructed of fire-resisting material, which booth must be ventilated to the outside air that gases from a burning film may be quickly dissipated by the means of an electric exhaust fan. All openings should be equipped with automatic shutters suspended from a fusible link. While it was not unusual in the earlier days of the motion pictures to have the films take fire, the hazard has been so well safeguarded, largely through a more intelligent class of operators, that rarely do we hear of such fires.

The booths in which the moving picture machines are operated are generally made of an angle iron frame, the sides and tops of which are covered with asbestos building lumber, generally called transite, ¼ inch thick, securely bolted to the frame. The floor is covered with the same material, ⅜ inch thick.

## FILMS.

The non-inflammable film, which does not burn with a flame and which does not easily ignite, has not been the commercial success hoped for and is but little used in the standard sized machines operated in the theatres and in other public places. There is, however, a smaller equipment which is permitted to be used without the booth required for the larger equipments. These miniature equipments require a special sized film, and will not take the films of the commercial size. These equipments must never consume more than 600 watts. The films used are of an approved slow-burning type having a permanent distinctive marker.



Courtesy of Nicholas Power Company.

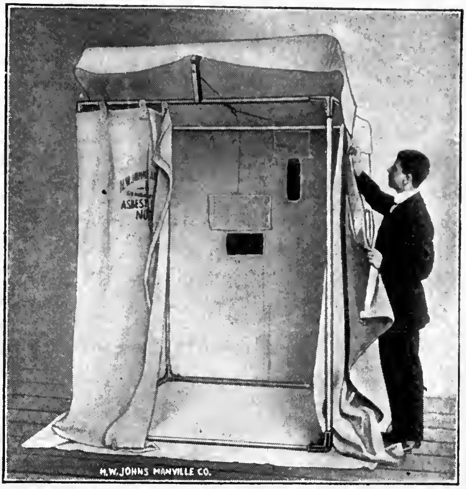
Complete equipment of Power's Cameragraph No. 6, which is a hand driven machine.


Courtesy of H. W. Johns Manville Co.

A standard booth for a moving picture machine equipment. This consists of frames of angle iron, covered with transite, or asbestos lumber, the frames being bolted together. At the bottom of 4 sides of the booth are openings covered with wire cloth of fine mesh for ventilating purposes. A metal vent pipe extends from the top of the booth to the outside air.

## MOTION PICTURE FACTORIES, STUDIOS AND EXCHANGES.

The greatest hazard of the moving picture industry is to be found in the Factories, Studios and Exchanges because of the great amount of film used and, frequently, the limited time used in handling them. A Moving Picture Factory, Studio or Exchange is considered as that building or portion of a building in which moving picture films are manufactured, exposed, developed, printed, rewound, repaired, stored, etc. The electrical equipment must be on lines similar to those required for a theatre, the lamps to be so installed that they could not come in contact with a film. All current-breaking devices for the electrical equipment must be enclosed in approved dustproof and fireproof cabinet, while all motors must be of the induction type. Where Direct Current motors, however, must be used, they must have enclosed commutators. The films must be kept in safes, vaults or cabinets, which must be ventilated to the outside air. All scrap or waste shall be kept under water, in self-closing standard metal cans or their equivalent and any cement having collodion and amyl acetate or similarly inflammable compounds shall not exceed the quantity required for one day, inside of the building, and shall be limited to one gallon.




Courtesy of the H. W. Johns Manville Company.

A moving picture booth of the portable type.

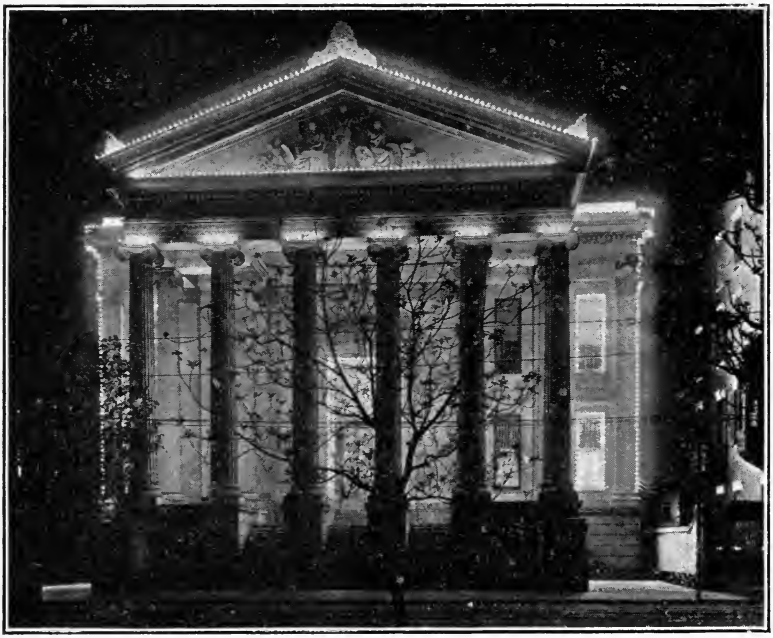
## OUTLINE LIGHTING.

This is a form of decorative lighting, which is most generally installed in a permanent form, in which rows of incandescent lamps are used on the exterior of buildings to outline some of the architectural features. The former method of lighting the dome on the Capitol, at Hartford, was through outline lighting, in which each lamp had its distinctive place. Such systems are sometimes installed inside of buildings when the regular rules for inside installations are to be followed. Outline lighting on the outside of buildings, however, may have special characteristics. Only systems under 550 volts may be used in either open work or in conduit. When open work is used, the rules for wiring in damp places should be followed. These rules, you will recall, require that the wires be 2½ inches from each other and 1 inch from the surface wired over. The circuits for outline lighting should have their own separate switches and fuses, which must, if installed on the outside of buildings, be installed in approved weatherproof cabinets. The switches must never be of the single-pole type and circuits must be so arranged that not more than 1320 watts will be dependent upon one cut-out.

## ELECTRIC SIGNS.

The subject of electric signs has developed into a science of itself. It is not my purpose to pass upon the general hazards of large signs and the obstruction they offer to firemen. Signs should be substantially built because of their exposure to the high winds and other elements. Preferably, they should be constructed of metal. The wires should have rubber insulation and should be soldered to the terminals of receptacles. The flashing or animating is accomplished by a machine known as a "flasher", which is really a number of switches operated by a motor-driven drum.

The location of a sign flasher should be such as to remove it from chance of accidental injury or tampering, to permit the direct and well arranged running of circuits to it, and to render it accessible for cleaning, adjusting and inspecting. A flasher should never be installed in a closet or other inaccessible place, and should be installed in a strong metal cabinet.



Courtesy of Crouse-Hines Co.

The building pictured above is the City Hall at New Orleans, La. Every lamp in the outlining is held in a receptacle, mounted on a fitting which protects the wires and lamps from the weather. The circuit wires are installed in rigid conduits and because of the nature of the fittings used the lamps are not enclosed in sealed globes.

Courtesy of Hanlon and Murphy.

Connecticut River Bridge at Hartford, Conn.

## CAR WIRING.

In the rules for the wiring of electric cars, and the equipment of such cars, two provisions are to be considered. The protection of car bodies and woodwork over all of the electrical apparatus such as motors, resistance, contactors, heaters, and the like, and over such of the conductors as are not installed in conduit. The other provides for wires, cables, and methods of making joints and connections in them, to the location and type of fuse and circuit-breakers to be used, to special forms of conduit and moulding, and to details of the lighting, heating, and air-pump circuits. As all of these requirements are somewhat outside the range of this course, I would suggest that the current issue of the National Electrical Code be studied in detail.

## CAR HOUSES AND SHOPS.

Car houses and car repair shops have electrical hazards which can be greatly minimized by close adherence to the special rules which are determined chiefly by the fact that the railway circuit is grounded and this requires different treatment than the ordinary light and power circuits. The trolley wires must be securely supported on insulating hangers, the hangers to be so spaced that should a trolley wire break, contact with the floor cannot be made. There should be an emergency switch outside of the building, that all the trolley wires in the building may be cut out at one point, and the trolley wire be dead at all points within 100 feet of the building. It is also desired that the lighting and power systems be so installed that one main switch may control the installation independently of the main cut-out switch outside of the building. That the amount of current may be limited, it is desirable that the installation be fed through an automatic circuit-breaker. It is now the practice to install the wires of the lighting and power circuits in a car house or a car repair shop in metal conduits.

## LIGHTING AND POWER FROM RAILWAY WIRES.

It should be remembered that the trolley wires of a railway system have a grounded return and that the wires are exposed to lightning. For this reason, in other than railway properties, it must be noted that under no circumstances should current for electric lighting or power be taken from trolley or third-rail railway circuits with a grounded return. The inevitable fluctuation in voltage would frequently require overfusing of the circuits to prevent blowing of fuses under normal conditions. Then a circuit, grounded to earth, with so much capacity behind it should be kept out of factories and buildings of all kinds, except, as noted, in railway properties.

## GARAGES.

In garages, in which vehicles carrying volatile inflammable liquid for fuel or power are kept, for whatever purpose, we have a hazard which is not directly of an electrical nature but which may be greatly increased through an imperfect electrical installation. All feed and circuit wires should be installed in conduit or armored cables and all outlet, switch and junction boxes should be located at least 4 feet from the floor. All cut-outs, switches, receptacles and any device having a current breaking part must be placed at least 4 feet from the floor, that the vapor from gasoline, due to leaks, cannot be ignited by the arc caused by breaking the circuit. All portable lights must have keyless sockets of moulded composition or metal sheathed porcelain type, which sockets must be equipped with handle, hook and substantial guard. Motors and dynamos, not a part of a vehicle, if not located at least 4 feet from the floor must be of the fully enclosed type.

## ELECTRIC CRANES.

The chief hazard of electric cranes is to be found in the collector wires, which wires must necessarily be bare. These wires must be so mounted on insulating supports, that even with extreme movements the wires will be separated at all times at least 1½ inches from the surface wired over. In the horizontal runs of the collector wires, they should be so supported that the wires will be at least 6 inches apart. Owing to the intermittent load on the motors the resistances are heated considerably, requiring location for ample ventilation. The motor frames, and the entire frame of the crane and the tracks must be permanently and effectually grounded.

## LIST OF APPROVED FITTINGS.

You will recall that during our first lecture reference was made to the list of Approved Fittings. No care in installing electrical equipments will entirely compensate for the use of inferior or defective devices. The National Board of Fire Underwriters has for many years maintained a system of tests and examinations of electrical appliances, and issues twice a year a "List of Electrical Appliances" which contains a classified form under the names of their manufacturers all of the standard and special fittings and materials which have been approved.

These tests and examinations are made and the approvals are issued by the Underwriters' Laboratories. The constructional details of electrical fittings and materials together with the chief tests to which they are subjected, prior to approval, are contained in what is known as Class "D", of the National Electrical Code, to which 82 pages are devoted to the specifications of electrical fittings and materials, that, in so far as the manufacturers are concerned, electrical installations may be free from fire hazards.

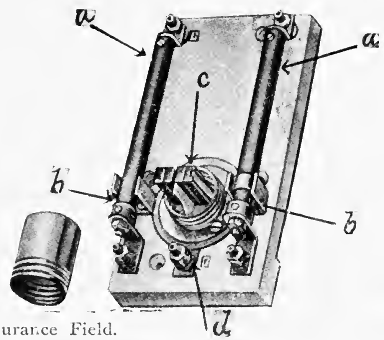
## SIGNALING SYSTEMS.

The rules for signaling systems govern wiring for telephone, telegraph, (except wireless telegraph apparatus) district messenger, call bell circuits, fire and burglar alarms and similar systems which are dangerous and hazardous only because of their liability to become crossed with electric light, heat or power circuits, or from lightning. When on pole lines with wires for electric light and power, the signaling wires, being smaller and more liable to break and fall, should generally be placed on the lower cross-arms. When run underground, they should never be in the same duct or man-hole with electric light or power wires, owing to the possibility of the two systems becoming crossed. When these systems enter a building from an overhead pole line, they should be provided with proper protection at the point where the wires enter the building, there being a secondary hazard to these signaling systems, owing to the fact that in the extent and ramification of all electrical wires there are liabilities of mishap when, through accident, there is contact of the wires of different systems, and lighting or power currents are imposed upon the delicate apparatus of the telephone system; and this hazard is set aside by the operation of protectors.

## PROTECTORS TO SIGNALING SYSTEMS.

At the ends of the telephone lines destructive results from such foreign currents are prevented by apparatus which is sub-divided into the various functions which it performs, for there has not been thus far any single device of defending the telephone instruments against the whole range of commercial foreign currents and lightning to which they are subjected.

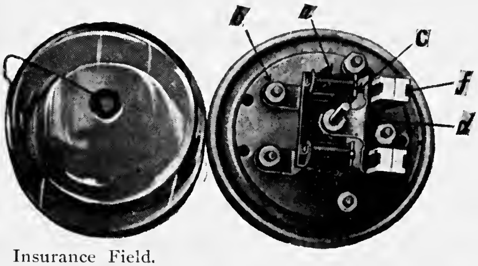
The first element consists of a fuse made of an alloy which forms part of the circuit, and is contained in a tube of vulcanized fiber. These fuses will deflagrate when exposed to currents of 7 to 10 amperes, the capacity of the fuse varies according to the type of apparatus.




Courtesy of The Insurance Field.

Standard protector used by the American Telephone and Telegraph Co. a-a are the enclosed fuses, b-b, heat coils. If a grounded current of a pressure greater than 300 volts enters the building, it will jump the air space between the lightning arrester C to the ground plate D.

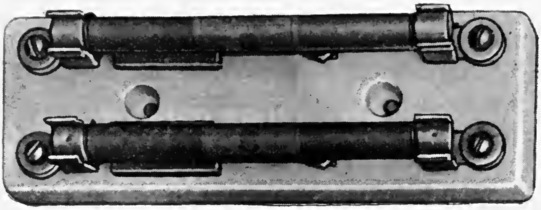
The next element consists of a pair of small blocks of carbon whose larger surface measures about one-half inch, and one of these blocks is connected to the telephone circuit. The corresponding block of the pair of carbons is separated from it by a perforated sheet of iron and is electrically connected with the earth. A small cavity in one of the opposite faces of the carbon is filled with a button of solder such as used in automatic sprinklers, and which melts at 160 degrees Fahr. The distance between these carbons or the thickness of the mica, is .0055 inch, being such that electricity at over 350 volts will pass from the carbon connected with the telephone circuit across this space to the opposite carbon and thence to the earth, thereby relieving the telephonic apparatus of electrical tension exceeding 350 volts.




Courtesy of The Insurance Field.

At "a" in the above picture is shown a heat coil mounted between the line and instrument terminals b & c, the spring c being thereby held at a tension. As soon as the fused metal in the coil melts, spring c is released and flies back, opening the line to the instrument and coming into contact with ground connection d, lets the current from the outside line be carried straight to earth over the ground wire. If this is a heavy current it will blow the fuses which have been placed in the line ahead and cut the wires out of circuit. The lightning arresters are shown at f.

Thus, if the foreign current exceeds the carrying capacity of the tubular fuse, its deflagration opens the circuit at that point. If, however, it is less in volume than the carrying capacity of the fuse, and over 350 volts tension, it leaps across the thin space separating the carbons, and thence passes to earth. The resistance of the small arc in the space between the carbons is sufficient to slightly warm the carbons, and cause the fusible metal to flow from its recess and fill the space between the carbons, and thus establishes a conductor of low resistance to earth. This diminished resistance generally causes a sufficient increase in the current imposed upon a line to cause the tubular fuse to deflagrate and open the circuit, if it did not do so on the first occurrence of the contact which imposed the foreign current on the telephone circuit.



Courtesy of The Insurance Field.

A type of protector used where heat coils are unnecessary.

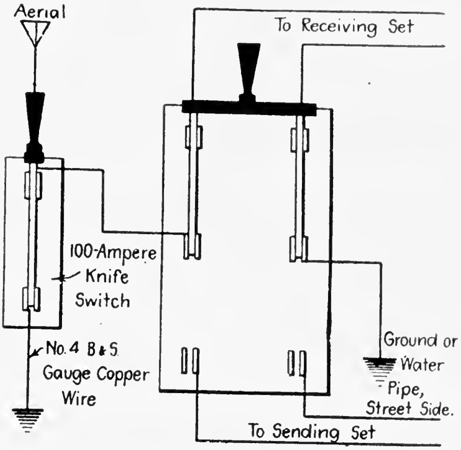
In order to protect the fine wires of the telephonic apparatus from injury by currents which are too small to operate the tubular fuse, and of too low tension to pass to earth through the carbon cutouts, a third element known as the heat coil is employed, in which a fine German silver wire which forms a part of the telephone circuit will be heated by a current on $1/6$ ampere to a temperature sufficient to release a conductor ordinarily secured by fusible solder, and pass the current to earth. The result of this protective apparatus is to guard against mishaps to the apparatus resulting from foreign currents and lightning.

## WIRELESS TELEGRAPH APPARATUS.

Another form of signaling system has come into popular use in the form of wireless telegraphy. This consists of a number of bare wires supported through insulators on wooden spreaders, which spreaders are supported overhead, generally, from wooden masts, and because of the exposure to the elements, are liable to high potential surges from high-potential transmission lines within the range of the apparatus and from lightning. When these equipments are not in use, they should be effectively connected to earth that the surges and lightning discharges may have an easy path to ground.

## MARINE INSTALLATIONS.

These installations are on vessels and must be well protected against moisture, since the salt air and fogs destroy ordinary fittings and materials. The rules for this type of installation differs from the standard rules in that special care is necessary to guard against the effects of constant and




Grounding aerial by knife switch on outside of building.

severe vibration, dampness and extreme hard usage to which installations of vessels are always subjected. Wires are usually installed in conduit or in moulding. Lead encased cables have been used in the wiring of battleships, but such method of installation has not been a success owing to the cracking of the protective lead covering which permitted moisture to enter and in a short time the rubber insulation was destroyed.

## ELECTRICAL FIRE HAZARDS

### (A Review.)

In electric power installations, attention should be given to the following features:—

(a) Switchboards of wood or wood-skeleton type, treated with oil, varnish or insulating compound, are of antiquated type, and should be replaced by those of modern design, constructed entirely of non-combustible, non-absorptive, insulating materials. Switchboards built of planks closely nailed together are especially dangerous.

(b) All switchboards must be provided with a reliable ground-detecting device and necessary circuit breakers or fuses of a standard type.

(c) Observe that terminals of underground conduit or ducts at both generator and switchboard are properly sealed and so located as to prevent the entrance of water or dirt therein. All such terminals should extend above floor line the full limit of available space.

(d) Fuses require constant supervision and should be preferably of the enclosed type.

(e) Space behind switchboard must be kept free from rubbish or combustible materials.

(f) All outgoing lines should be provided with approved lightning arresters.

(g) The arrangement and spacing of cables should be observed. Even in instances of lead covered cables an arc may melt off the lead and burn the insulation. Cables should not be too closely bunched or grouped; extensive damage to insulation may result from fire in bunched cables.

(h) Old-fashioned oil switches with open top and wooden interiors, where found, should be replaced with approved devices.

(i) Current transmitted from high-voltage lines should enter transformers properly installed outside of buildings, or in a well ventilated fireproof vault properly cut-off. Oil-filled transformers should always be surrounded by a curbing of sufficient height to contain as much oil as is contained in the transformers themselves, and ample drainage should be provided at floor level. Note that oil-filled transformers should never be installed inside of main building, if possible to avoid it.

(j) No oils or volatiles of any kind should be kept in generator room except the daily supply of lubricating oils in metal receptacles. There should be no accumulations of dry or used waste in generator room. Adequate standard metal waste cans and hand fire protection should be installed.

## ELECTRIC MOTORS.

All motors should be installed in a dry and well lighted location, to which free access may be had at all times.

(a) Motors should be equipped with a substantial metal drip pan to catch all waste oil.

(b) All motors, regardless of size, should be protected by proper fuses or circuit breakers, and switches at each motor should be of a type that will positively cut-off all current when motor is not in operation. All starting boxes and controlling devices, except in specially authorized cases, should be in immediate sight of motor.

(c) All motors installed in dusty and dirty places where readily ignitable material is present, should be of enclosed type or be placed in enclosures constructed preferably of non-combustible material with ample amount of fine wire screen to afford good ventilation.

(d) To avoid such locations where possible, it is advisable that motor should drive machinery through the medium of a shaft fitting tightly in a wall bushing, motor being on opposite side of wall or partition.

(e) All rheostats and starting boxes, unless mounted on switchboards, should be mounted on slate or other non-combustible insulating material, unless mounted on substantial brackets which will separate them one foot from combustible material, or unless mounted on cement or concrete walls or floors.

(f) Motors must be of sufficient capacity; must be kept clean, must be regularly oiled and otherwise given proper care, and commutators kept smooth.

(g) Motors should be in care of a competent man who should periodically inspect them.

## ELECTRIC LIGHTING HAZARDS.

All equipments for electric lighting, heating, etc. should conform to the following, which are suggestions for field practice.

(a) All wires must be properly supported, insulated and protected against mechanical injury, so that system may be kept free from grounds and short circuits. Observe whether ground wires for conduit and secondary systems remain undisturbed and that connections of ground wires to conduit and water pipe or other grounded metal work are also undisturbed and in good order. Telephone, bell, and other signal wires should also be observed and be made free from contact with electric light wires. Crosses outside are frequently as dangerous as inside of buildings. Recommend that wires be made rigid and free from sagging.

(b) Wires must be of ample capacity to prevent overheating; all joints must be properly soldered and taped so as to insure perfect contact; wires must be protected by fuses of proper size and of approved type against overload and short circuits.

(c) If installed in the vicinity of easily ignitable material, cut-outs must be enclosed in standard cabinets. If not of metal, cabinets must be properly lined. Door, latch, and hinges should be kept in proper order. Cut-outs and switches must not be installed in rooms subjected to inflammable vapors, nor in rooms wherein hazardous processes are conducted, unless by special permission and provision for special safeguards.

(d) Where volatile vapors or dangerous explosives are prevalent, suggest conduit system of wiring and the use of vapor-proof globes. Switches and cut-outs controlling these circuits should be installed outside of the room where any hazardous process is conducted, unless by special permission and provision for special safeguards. Where necessary, suggest the use of metal guards about swinging globes.

(e) See that all fuses are of standard type and in good condition. Suggest the removal of substitutes, such as nails, hairpins, and the like. Observe contact parts of cartridge fuse blocks.

(f) Observe if all fixtures are properly connected and supported; ascertain if any circuits are overloaded by attachment of too many lamps.

(g) All pendant lamps must be provided with approved cord, and be free from contact with furniture, nails, pipes, machinery, and other fixtures. Lamps of a portable type must be equipped with approved reinforced cord, to insure protection against abrasion. Heavy guards are recommended for lamps attached to portable cords.

(h) Condemn the use of paper and other combustible shades on lamps. Where shades are necessary, suggest those of a non-combustible type. Recommend the removal of any temporary attachments, artistic displays, and extensions improperly made.

(i) Electric heating devices should be protected against danger of communicating fire to adjacent materials, as to construction, connection and mounting. Note the installation of special apparatus such as electric welding machines, electric furnaces and ovens, cloth cutters, etc., etc., and if such apparatus appears carelessly or improperly installed, notify or confer with the inspection department having jurisdiction.

(j) Lighting and power from railway wires must not be permitted under any pretense on the same circuit with trolley wires with a ground return, except in railway cars, electric car houses, power houses, passenger and freight stations connected with the operation of electric railways.

(k) Obsolete types of electrical equipments are occasionally met with, especially hazardous features of which are wooden cleats, rosettes, and fuse blocks, knife switches of unsafe dimensions, often mounted upon wooden bases and wooden case rheostats. Wires and flexible cord in such instances will be found to have very inferior insulation. Equipments of this character should usually be replaced, as in most cases they may be considered as beyond possible repair short of a new installation.

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