The National Electrical Code.

AN ANALYSIS AND EXPLANATION OF THE UNDERWRITERS' ELECTRICAL CODE, INTELLIGIBLE TO NON-EXPERTS.

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Publisher's Announcement.

In response to many requests, the notable articles on "The National Electrical Code," by Pierce and Richardson, in "The Insurance Post" of Chicago, have been revised and extended and are published herewith in convenient book form. As stated in the sub-title, this little book is "An Analysis and Explanation Of The Underwriters' Electrical Code, Intelligible to Non-Experts." Most writers on electrical topics confuse the non-expert by their continued use of technical terms. Messrs. Pierce and Richardson, whose competency is unquestioned, have undertaken "to explain the matter in ordinary language," for the special benefit of insurance inspectors and electrical students. Hence, also, the common analogies and simple definitions.

On the authority of eminent electricians, the Underwriters' Code is to-day the best guide to safe construction and certain provision against loss by fire. The joint work of advanced underwriters and experienced electricians, it represents years of patient research and the accumulated knowledge of recognized experts. A study of its rules and requirements has been often urged upon central station men and engineers. Insurance companies and their representatives, meanwhile, have come to look to the Code for instruction and guidance, but without knowing why or wherefore. The whys and wherefores are clearly set forth in the following pages; and now that Electricity is coming into general use, the necessity of a better knowledge of electrical hazards is freely admitted by all those engaged in fire insurance.

Supplemental to the general exposition, properly classified and indexed, is the "Appendix," in which will be found tables and curves for measuring wires, and the full text of the Underwriters' National Electrical Code for 1896. The writings of Messrs. Pierce and Richardson, it is proper to add, have attracted the favorable notice of prominent underwriters, architects, builders and engineers. It is believed that this little book will prove indispensable to most insurance inspectors and special agents, and of practical interest and value to many electricians.

C. A. H.

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CHAPTER XXI.

The National Electrical Code.

CHAPTER I.

INTRODUCTORY AND DEFINITIONS OF COMMON TERMS.

With the exception of those who are directly engaged in electrical employments, or are investing their money in electrical plants or enterprises, no one has a more direct interest in the proper construction of electrical work than the representatives of insurance companies. To-day the insurance agent duly appreciates if he does not even overestimate, the hazard that may be caused by faulty electrical construction. How to recognize this hazard when he sees it, and how to avoid it, is, however, a difficult and often an unsolved problem. When the question of safety is one of ordinary building construction, the hazard is easily seen, when once it has been pointed out, and the remedy is usually as easily described and understood. When we come to electrical matters, however, we often find that the mind of nearly every one, except the so-called electrical expert, is more or less befogged. An explanation does not always explain, and even when one concludes that he has obtained a clear and satisfactory understanding of a hazard and its remedy, he is straightway confronted with some astounding statement or some apparently mysterious phenomena.

It has occurred to us that possibly the principal reason why most persons have such an indefinite knowledge of even the simple things in the application of electricity is, that electricity has almost a language of its own. Every description of anything electrical by an electrician, is filled with such terms as "volts," "amperes," "ohms," "rheostats," "induction," "electro-motive force," etc., etc. Every day adds new words to this peculiar vocabulary, so that even the electrical engineer has to be well-read, to keep track of all these electrical terms. A good sized electrical dictionary has already been published, but this would have to be revised as often as the Chicago city directory to keep up with the inventive genius of the men who coin electrical terms. While these electrical terms are useful and necessary, still it seems to us that their great number has discouraged many from the study of practical things which they wish to know, and which are easily understood if expressed or explained in common, every-day language. It is our intention in this and succeeding chapters, to discuss that part of electrical construction which has a direct bearing on the question of *safety*, and it will be our aim to do this, as far as is possible, in ordinary language, avoiding technical expressions when we can, and when they cannot be avoided, as must often be the case, we shall try to give a simple explanation or definition of the expressions, not going into a scientific discussion, or trying to give definitions which shall be logically and mathematically precise, but simply giving such explanation as will, we hope, enable the unscientific reader to form a conception of what is going on in a system of electrical wires, and to see clearly why one thing is safe and another is not.

We do not propose to assume that the reader knows anything at all about electricity, and we offer our apologies right here to any who may feel that their intelligence is insulted. We also apologize to those who have struggled to explain the same thing in technical language and mathematical formulæ, for our audacity of undertaking a task at which so many of them have been unsuccessful. We are not prompted by conceit in our undertaking. Like all who have long been engaged in electrical work, we have been met daily, for years, with questions of all kinds from men who had no time to study technical works, but who wanted a simple explanation of something electrical. Usually we have been able to explain the matter in question in ordinary language to the satisfaction of the inquirer, and often we have had a man go away with the knowledge of the subject which answered his purpose perfectly, and was doubtless infinitely more satisfactory to him than our understanding was to us. We feel, therefore, that our undertaking is a laudable one, and if our success is not equal to our expectation, we hope that we shall, at least, help to open a path for others. It is, of course, impossible in this book, to cover the entire field of electrical construction or even the applications of electricity that might interest our readers. We have, therefore, decided to take up the subject purely from the insurance man's point of view. We shall consider only electricity as it may or may not create a *hazard.*

This subject has been carefully and very completely covered in the rules known as the "National Code." This code in its original form, or as revised and incorporated into the regulations of the various insurance associations, is familiar to every one in insurance lines. It is, however, condensed in form, and full of technical terms. We have, therefore, thought it proper to take this code as our text. We shall endeavor to explain the code in every-day language, giving such definitions and explanations as will, we hope, enable any one to understand its meaning without the assistance of an electrical dictionary or electrical text books. We shall take up the various points in the same order that they are taken up in the code. The National Code is the outcome of experience. It is the result of a great amount of study and discussion. It stands to-day as the best expression of what is definitely believed by the ablest men of both insurance and electrical lines, and if we shall succeed in assisting any one to a better understanding and appreciation of its principles, we shall feel repaid for our efforts. The following definitions are absolutely necessary to describe the most common terms which constantly appear in the code.

Electricity.—We do not know what electricity is, and it is useless for us to try to define it. We perceive it as a manifestation of energy. All we need to know of its nature for our present use, is that we can transform the work of an engine or water-wheel into electricity, and that we can direct and regulate its distribution by wires or conductors, and transform it again into energy in the form of light, heat, or work, in moving a machine. There is but one kind of electricity, as far as we know, but it manifests itself to us in various ways. In the production of light, heat and power, we deal only with dynamical electricity, or electricity in motion.

Electric Current.—While we have to deal with electricity in motion, still, as its nature is not known, its motion is but imperfectly understood. It is necessary for us, however, to have *some* theory to account for its actions. For all ordinary purposes, we may consider electricity to be a fluid, and to have a motion in a wire like water in a pipe. Following this analogy, we speak of a "*current*" of electricity. As with water in a pipe or a river, so with electricity, the *amount of flow* is proportional to the *strength of the current*, and to the *time* during which it flows. The *rate* of flow of electricity is called "the current strength," or, more commonly, the "*current.*" It is measured by an arbitrary standard called an "ampere." *The ampere is the unit of current strength.* The total *amount* of electricity flowing will, of course, be measured in "*ampere hours.*" For example, an ordinary 2,000 c. p. arc lamp, such as is commonly used in street illumination, requires a current of 10 amperes. If the lamp burns for 10 hours, the total amount of current consumed will be 100 ampere hours. When we speak of a wire carrying a current of 10 amperes, we mean that 10 units of current are flowing in the wire, and we use the expression in the same way as if we were to say of water, that a current of 10 gallons per minute was flowing through a pipe.

Electro-Motive Force—Pressure or Potential.—These terms are all used in the code to express the same thing. We will use the more common term of "electro-motive force," which is commonly abbreviated to E. M. F. E. M. F. may be defined as a force which causes, or tends to cause, a current of electricity to flow. To use our same analogy, suppose we have a tank full of water; we shall have upon the bottom of a tank a pressure due to the head. If we bore a hole into the bottom of the tank, we shall immediately have a flow of water. If we place our hand over the hole, the pressure will still *tend* to cause a flow and the flow will be instantaneous as soon as the obstacle is removed. In electricity we measure the pressure by an arbitrary unit called a "volt." This corresponds with the pounds of pressure to the square inch with water. With water, the greater the pressure the greater will be the flow, the outlet remaining the same; so with electricity. The greater the E. M. F., the greater will be the current, provided other conditions remain unchanged. In fact, with electricity, the relation of flow to pressure is more simple than with water, for, other things remaining the same, if we double our pressure, we double our current, *i. e.*, the current will be exactly proportional to the pressure; or the amperes will be proportional to the volts.

Dynamo.—A dynamo is a machine which, when driven by an engine or other source of power, transforms the work of the engine or prime mover into electricity. It may be compared to a pump driven by a belt. When motion is transmitted to the pump, it sets up a pressure which will cause, or tend to cause, a flow of water. So, when a dynamo is set in motion by any mechanical means, an electrical pressure will be set up, and this is called the "pressure" or "E. M. F." of the machine. This pressure will tend to cause a flow of electricity, or an electrical current.

A dynamo is a reversible machine, *i. e.*, it can be used to generate a current of electricity, or, if the current of electricity is produced by another source, and sent through it, its armature or moving part will be set in rotation and it can be used as a source of power to drive other machines. When thus used it is called a "motor." The distinction between a dynamo and a motor is one of application, and not necessarily of construction. To make the distinction clear, it is now common to speak of a machine which generates electricity as a "generator," and of one which transforms electricity into mechanical work as a "motor." The words "dynamo" and "generator" are used in the code to mean the same thing.

Conductor.—Unlike water, electricity does not flow most readily when not impeded by a solid substance. In fact, while no ordinary pressure will cause electricity to pass through the air, a small pressure may cause an immense current to flow through a mass of metal. We therefore say that metal is a conductor of electricity, and that air is a non-conductor.

When we wish to direct a current of water from one point to another, we provide a path free from solid obstruction and we confine the water through this path by some solid substance, such as the bank of a canal or a metal pipe. With electricity, however, we provide a metallic path, such as a copper wire, and the electricity is kept from leaving the wire by the surrounding air, or some other non-conducting material which separates the wire or metal path from other paths into which it might flow if there was no such barrier.

Resistance.—Although electricity will readily flow in a metal wire, a given pressure will not produce the same flow in wires of different metals, or in different sized wires of the same metal. Just as with water, a given pressure will not send the same amount through a small hole as through a large one, or through a long pipe of small diameter, as through a short one of large diameter, so a given E. M. F. will send a small current through a long, thin wire, and a strong current through a short and thick one. We explain the different results by saying that the long, thin wire offers a "resistance" to the flow of the current. This we call "electrical resistance," or simply "resistance." Resistance is measured in "ohms," an ohm being an arbitrary unit.

Electrical resistance may be compared to friction in a pipe carrying a current of water; the greater the pressure, and the less the friction, the greater will be the flow. So, in electricity, the greater the E. M. F., and the less the resistance in the path or conductor, the greater will be the current. Or, to express the same thing in electrical terms, the greater the voltage of our dynamo, and the less the resistance of our conductor in ohms, the greater will be the current in amperes which will flow through the conductor.

Insulator.—If we are to confine electricity to our "conductor," we must separate it from other conductors; or, as we say, we must "*insulate*" it. This is accomplished by surrounding our conductor with a non-conducting substance, or by supporting it by a non-conducting substance in the air, which is itself a non-conductor. Any such non-conducting material used to support or surround a wire is called an insulator. In practice it is customary to speak of a non-conducting support as an "*insulator*," and of a non-conducting material surrounding a conductor or wire as "*insulation.*" It is evident that the distinction between "insulators" and "conductors" is simply relative. A non-conducting or insulating substance is simply a substance of very high resistance, but the resistance of materials used for insulation are so enormous, that we are justified in calling them "non-conductors." Of all insulators, dry air is the best, and dry glass the next best; rubber, porcelain, oil, shellac, mica, paper, cotton, silk, etc., are the substances most commonly used. As safety in electrical work depends solely upon the confining of the current to its proper circuit, the problem of safety is very largely one of insulation, and it will be seen that the greater part of the "code" is devoted to specifying material and methods which will secure good insulation.

Polarity.—The flow of current from a dynamo is not exactly analogous to the flow of water from a tank, since to have a continuous current of electricity, we must have a *continuous conducting circuit; i. e.*, the current must flow *from* the dynamo *through* the circuit and *back* again to the dynamo. In this respect the dynamo is more like our pump. We must continually supply water to the pump in order to have a continuous flow. Any electrical circuit must be *continuous* in order to have a current, and we may, if we like, imagine the condition similar to that of water flowing round and round in an endless pipe. We assume that any ordinary current flows always in the same direction, and that the current from a dynamo goes out from the machine on one conductor, and back to the machine on another. We express this by saying that these two conductors are of "*opposite polarity*," and the points where they join the dynamo we designate as the two "*poles*" of the machine. The pole where the current emerges is called the "positive" pole, and the one to which it returns is called the "negative" pole. "Polarity" is naturally relative, and we speak of any part of a circuit as being positive with reference to another, when the current flows from the first point to the second, or when the pressure tends to set up such a current. Other electrical terms which appear in the "code" will be defined as we come to them.

CHAPTER II.

CENTRAL STATIONS FOR LIGHT AND POWER. PART I.

TEXT OF CODE ON CENTRAL STATIONS. CLASS A. (These Rules also apply to dynamo rooms in isolated plants, connected with or detached from buildings used for other purposes; also to all varieties of apparatus therein of both high and low potential.)

1. GENERATORS:—*a*. Must be located in a dry place. *b*. Must be insulated on floors or base frames, which must be kept filled, to prevent absorption of moisture, and also kept clean and dry. *c*. Must never be placed in a room where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases, or flyings, or combustible material. *d*. Must each be provided with a waterproof covering.

2. CARE AND ATTENDANCE:—A competent man must be kept on duty in the room where generators are operating. Oily waste must be kept in *approved* metal cans, and removed daily.

3. CONDUCTORS:—From generators, switch boards, rheostats or other instruments, and thence to outside lines, conductors—*a*. Must be in plain sight and readily accessible. *b*. Must be wholly on non-combustible insulators, such as glass or porcelain. *c*. Must be separated from contact with floors, partitions or walls through which they may pass, by non-combustible insulating tubes, such as glass or porcelain. *d*. Must be kept rigidly so far apart that they cannot come in contact. *e*. Must be covered with non-inflammable insulating material sufficient to prevent accidental contact, except that "bus bars" may be made of bare metal. *f*. Must have ample carrying capacity, to prevent heating.

The name "Central Station" is applied to any electrical plant from which electricity is furnished for operating street lights or for supplying electricity for lamps or motors, in a similar manner to that in which a gas company furnishes gas for heat and light. By an "Isolated Plant" is meant an electrical plant for lighting a single building or a number of buildings owned by one person or company. The distinction is not arbitrary, and it will be noted that the code lays down the same rules for the installation of machinery and apparatus in the dynamo room of an isolated plant as in a building devoted exclusively to an electric plant. So we will not try to give any more precise definition than the above. A Central Station has extra hazards due to its outside lines on poles or underground, which may accidentally come into contact with the ground, with one another or with the wires of other systems; or may, if improperly installed, conduct lightning into the station. In installing an isolated plant, on the other hand, equal care is necessary, as any hazard to the plant endangers the building in which it is located, and also the contents of the building.

Before discussing electrical construction, let us consider how it is that an electrical current can cause a hazard. If a current flows in a wire, we have found that its flow is opposed by something analogous to friction, which we have called resistance. The energy required to overcome this resistance is transformed into heat just as mechanical work expended to overcome friction is transformed into heat. The greater the current and the greater the resistance, the more energy will be absorbed in heating our wire. With a current of sufficient strength, we can heat any wire red hot, or, for that matter, we can melt it. If, therefore, our conductors are so installed that an accident may load them with an excessive current, we may have enough heat generated to char their insulation, or even to set fire to the insulation or any adjacent combustible material. We can prevent *undue heating* by using wires of proper size for the required current, and protecting them from a greater current by safety devices (described later); and we can secure additional safety by installing the wires in such a manner that even if they do become excessively hot, the heat will not be conducted to combustible material. Again, if we have a wire carrying a small current from a dynamo, and if we open the circuit, for example by cutting the wire, we will, upon separating the two ends, have a flash or "spark," as it is called. This spark gives out but little heat, but it will ignite an explosive mixture; we are all familiar with its use in electric gas lighting. If, however, the current be one of several amperes, when we separate the ends of our wires for a short distance, the current will flow across the gap. This is called an "*electric arc.*" It is a flame, and its heat is so intense that it will melt steel like wax in the flame of a candle. It is this arc that gives the light in an "arc" lamp, and this is the thing we may get in a system of conductors when wires of opposite polarity come in contact with one another, or when any accident breaks a wire carrying a large current. The current required for six or eight ordinary incandescent lamps will maintain an arc equal to that of a small arc lamp.

The accidental forming of an arc may be prevented by proper insulation and workmanship. Fortunately, we can, by proper workmanship and material and the use of simple devices, install our conductors so that we can obtain light and power with less hazard from electricity than from any other source. Poor insulation of conductors causes trouble by allowing the current to leave the conductor and flow through some other path. This improper path, like any other, must be *continuous*, *i. e.*, the current will not leak from the wire to a conducting substance in contact with it unless there is *another* contact where it can *return* to the circuit. *Two* contacts to a conducting substance are necessary to set up a leak. The substance may be some metal or any substance which can absorb moisture. Although pure water is a poor conductor, water which is dirty or which contains any salt or acid, in solution, is a good conductor. Most of the non-metallic material used in building construction is non-conducting when dry, but will conduct the current readily when wet. *The enemy of insulation is moisture.*

Generators.—A dry location is especially necessary for a generator. If moisture condenses upon the dynamo while it is not running, it may destroy the insulation of the wire with which it is wound. If the wire is simply covered with a thin covering of cotton, as is the usual practice, leaks may be set up between the different wires, resulting finally in the burning of the insulation; or the insulation between the earth and the conductors on the machine may be destroyed, thus endangering both dynamo and circuits. Further, where machines of very high E. M. F. are used, a damp floor or poorly insulated machine may endanger the life of the attendant, or at least discourage him from properly attending to the machine.

As the current always flows in a closed circuit, we must have *two* "faults" in our insulation in order to have a leak. When we have one fault, the second may come at any instant, and the first fault may set up a strain upon a weak point in the insulation and help to develop a second one. The most common cause of leakage in a Central Station system is formed by the conductor of a circuit coming in contact with the earth. This contact is called a "ground." It is common usage to speak of the contact of a wire with *any* conducting substance as a "ground," and when we have such a contact, we say that the wire is grounded upon the substance. For example, if a wire touched a gas pipe it would be grounded, and we would speak of it as being grounded on the pipe, even if the pipe were not connected to the earth.

The mounting of a dynamo upon an insulating base or frame as required by the code is desirable in a lighting plant, as an extra precaution. The wires upon the dynamo are insulated from the iron frame of the machine; but, as this insulation may be injured by an over-load, by lightning or by mechanical injury, the further precaution is taken of insulating the frame from the earth, as a leak from dynamo to earth may be more serious than one upon a circuit, as its extent is not limited by safety devices. The observance of rule "c" concerning generators is important. An arc may be formed by the breaking of a wire, or by the intentional opening of a circuit carrying current. It is impossible to guard against a spark in a dynamo room. The current in a dynamo is generated in the moving part or armature, and it is led to the circuit through an attachment to the armature called a "commutator" or "collector" (according to its design), the conductors of the circuit being electrically connected to the commutator or collector by stationary strips of copper or blocks of carbon called "*brushes.*" Any defect in design or workmanship, improper adjustment, overloading of the machine, or even the presence of dust, may at any time cause "sparking" at the brushes. The cover specified in rule "d" is to protect the machine while not in service from dirt and moisture, as from leaky pipes, defective roofs, etc. It may also prove useful to prevent damage by water in the extinguishing of an incipient fire.

Care and Attendance.—As a variety of accidents may cause a dynamo to spark so badly as to throw off sparks to a considerable distance, or may even cause the "burning out" of an armature, it needs no argument to show that an attendant ought always to be near. Any serious trouble on the circuit will usually be indicated in some manner in the dynamo room, and prompt inspection may discover a hazard in time to remove it without loss. The rule about *oily waste* should, of course, apply wherever waste is used. Its habit of indulging in spontaneous combustion, especially when it has a good chance to set fire to something else, is too well known to insurance men to call for comment.

Conductors.—Originally it was customary to place electrical instruments and regulating and controlling devices either directly upon the wall of the dynamo room or, at best, to mount them upon a wooden board fastened to the wall. The board was called a "*switch board.*" This name is now applied to any structure carrying instruments and regulating and controlling devices. In a dynamo room or station, all circuits from the dynamos are led to a main switch board, and thence the current is distributed by the necessary circuits to the lamps or motors. The switch board controls the entire output of the plant, and often carries many regulating and controlling devices and a large amount of complicated wiring. Many of the fires in the poorly constructed stations of the past have originated in the switch boards or their vicinity. It would seem evident that the wires to and from the switch board should be in sight and accessible; yet, in many plants, wires have been run from dynamo to switch board under wooden floors, and all the wires to and from the switch board have been crowded between the board and the wall in an inaccessible space. This has been done for appearance sake, it being easier for the constructor to conceal poor work than to do work in a mechanical and workmanlike manner. The unfortunate experience of insurance companies with central stations has been largely due to this kind of engineering. Rules "b" and "c" describe the safest possible kind of construction; *i. e.*, such that current cannot leak from the wires even if their insulating covering is defective, and even if the wires become overheated, the heat cannot be communicated to any combustible material. With such construction, a bare, red-hot wire would not set a fire.

As regards rule "d," no other rule for distances between wires can be laid down, but safe work can be done by having numerous insulating supports of proper design. We might add to the rule by saying: "Keep the conductors of opposite polarity as far apart as space and circumstances will permit." With conductors run upon glass or porcelain, it is more important to have the covering of the wire *fire* proof than *moisture* proof. Rule "e" is usually interpreted to mean that a high grade of insulated wire should be used, and that the insulation should have a flame-proof covering or braid. The best practice for a dry station is to use a fire-proof covering and to depend upon porcelain and glass for insulation in case of accidental dampness. It should be the engineer's aim to secure good insulation in any event, and to do it with the smallest possible amount of combustible material. In many cases, this means none at all. Where several dynamos are run in a power or incandescent lighting plant, it is common practice to lead all the circuits from the dynamos to one pair or set of conductors upon the switch board, and from these conductors to lead off all the lighting or power circuits. These main conductors are usually so large that flat copper bars are used instead of wires. These bars, as they carry the entire load of the plant, are called "*bus bars*." The bus bars are usually bolted fast in position, and, as there is no possibility of their getting out of place, it is perfectly safe to have them insulated only by their supports. The rule "g," concerning "*carrying capacity*," simply means that the wires must be large enough so that they will not *heat unduly* with any current that they may ever be called upon to carry. This subject is taken up more fully in another portion of the code.

CHAPTER III.

CENTRAL STATIONS FOR LIGHT AND POWER. PART II.

TEXT OF CODE COVERED BY THIS CHAPTER. 4. SWITCH BOARDS:—Should be approved before being placed. *a.* Must be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material. *b.* Must be accessible from all sides when the connections are on the back; or may be placed against a brick or stone wall when the wiring is entirely on the face. *c.* Must be kept free from moisture. *d.* Must be made of non-combustible material, or of hardwood in skeleton form, filled to prevent absorption of moisture. *e.* Bus bars must be equipped in accordance with Rule 3 for placing conductors.

5. RESISTANCE BOXES AND EQUALIZERS:—*a.* Must be equipped with metal or non-combustible frames. *b.* Must be placed on the switch board, or, if not thereon, at a distance of a foot from combustible material, or separated therefrom by a non-inflammable, non-absorptive, insulating material.

6. LIGHTNING ARRESTERS:—*a.* Must be attached to each side of every over-head circuit connected with the station. *b.* Must be mounted on non-combustible bases in plain sight on the switch board, or in an equally accessible place, away from combustible material. *c.* Must be connected with at least two "earths" by separate wires, not smaller than No. 6 B. & S., which must not be connected to any pipe within the building. *d.* Must be so constructed as not to maintain an arc after the discharge has passed.

Switch Boards.—Rule "a" covers in a general way the question of location, and common sense should enable any constructor to apply the rule in a particular case. The front of a switch board usually carries a number of instruments, switches and safety devices, so that in most cases it is desirable to place our conductors upon the back of the board. In a large plant there are usually a great many instruments and appliances, and as the dimensions of the switch board are limited both by the amount of space available and by the requirements of convenient operation, it is almost absolutely necessary to place the conductors behind the board. Originally, wires were placed behind the board so that rough and cheap work could be done. The work upon the back of a switch board should be as neat and mechanical as that upon the front, and this is a good test of the ability and the intent of the installing engineer.

"Accessible" in rule "b" should mean not only that the conductors must be readily accessible for inspection, but also that there must be ample room behind the switch board for a man to work and to do *good* work. This is essential, as it is often necessary for a man to work behind a board while the conductors are carrying current, or, as it is commonly expressed, while the board is carrying "live" circuits. When a board is placed against a brick wall, all wiring should of course be upon the face of the board, and it should not be allowable to attach conductors of any kind to the board by metal screws or bolts extending through the board.

Two kinds of switch board construction are allowable by the code. We may make our board entirely of slabs of slate or marble fastened to metal supports; or we may erect a wooden framing attaching to the front our instruments, switches and controlling devices, each appliance having its slate or marble base, and the conductors being supported on the back of the frame upon glass or porcelain insulators. Frame or "skeleton" construction may be made safe, but it requires more care and skill to do a neat-looking job of wiring upon a skeleton board than upon one of slate or marble, and the slate or marble board costs but little more than the bases which are required when a "skeleton" board is used. The superior appearance of a marble board usually justifies the slight additional expense. Marble is better than slate as an insulator, and but slightly more expensive. The purer the marble, the better; and where the switch board carries currents of very high pressures, the marble should be carefully selected, and should be free from any impurities that might impair its insulating qualities.

Resistance Boxes and Equalizers.—A Resistance Box or Rheostat is a regulating device introduced into an electric circuit for the purpose of reducing the current or the electro-motive force. It is simply, as its name indicates, a *resistance.* The earliest form in common use consisted of coils of wire of a poorly conducting material, such as iron or German silver. These coils were mounted in a box, and the top of the box carried a switch, by means of which more or fewer coils could be introduced into the circuit, so that by turning a handle or wheel the resistance of a circuit could be varied. When we add resistance to a circuit, the E. M. F. or pressure which tends to send a current through our lamps or motors is decreased, and if the rest of our circuit remains unchanged, the current will also be *proportionately* decreased. A rheostat corresponds to the throttle on a steam engine. When a rheostat is used for controlling a current in the magnet or "field" circuit of a dynamo, it is called a "Dynamo Rheostat" or "Field Regulator," or simply a "Resistance Box." When it is placed in the circuit of a motor it is called a "Starting Box" or "Rheostat." When rheostats are used to reduce the pressure upon a number of circuits having a common starting point, they are called "Equalizers." Where a rheostat is used in theatrical work for "turning down the lights," it is called a Dimmer. The most general term is "*Rheostat*," which applies to *any resistance that can be varied at will.*

The regulating of a current by inserting resistance always means a loss of energy. This energy is transformed into heat in the rheostat. In order to make a rheostat small enough to be used in commercial work, it is necessary to allow the wires to get pretty hot. It is therefore evident that rheostats should be carefully designed and installed. Perhaps the worst points of danger in many of the central stations of the past were in the Equalizer, made of coils of iron wire in wooden boxes. Rheostats may be made perfectly safe by making them wholly of non-inflammable material, and excluding all inflammable material from their vicinity. *They are sources of heat, and should be treated as "stoves."*

Lightning Arresters.—A lightning arrester is not a device to *arrest* lightning, although that is "what that name might imply." Lightning, when once it gets upon our wires, is always looking for a chance to get to earth, and a lightning arrester is a device intended to *assist* the lightning to get to the earth by an *easy path*, and thus prevent it from taking a path where it might cause fire or other damage. A lightning discharge has a sufficiently high electrical pressure to overcome the insulation of our wire. In fact, it will get to ground somewhere, even if it has to jump a considerable distance to the earth. It will take the easiest path. Without proper protection, this path may be through the insulation of our dynamo (especially if the iron frame of the dynamo is grounded), or it may be from our wire to a gas pipe in a fixture carrying both gas and electric lights, or it may be at any weak point in the insulation of our conductors from the earth.

Most forms of lightning arresters consist simply of a piece of conducting material brought close to another piece of conducting material, so that the two are separated only by a very small air gap. The most simple form consists of two rectangular plates of brass or carbon laid upon slate or marble so that their edges nearly touch, one plate being connected to our circuit which is to be protected, and the other to the earth. The adjacent edges are usually notched, as this assists the discharge. Although the E. M. F. of our dynamos will not cause a current to pass across a very small air gap, the E. M. F. of a lightning discharge is so high that the gap offers no apparent resistance to its passage. Such is the nature of electricity in this form that it may jump an air gap of considerable width, rather than pierce a comparatively poor insulation at another point not far away upon the same circuit.

The great danger from lightning is that it destroys our insulation. We have seen that although the pressure of an ordinary dynamo will not *cause* a current to pass over a very minute air gap, still when we touch two wires of opposite polarity together and then separate them the same pressure will *permanently maintain* an arc of considerable length. So when lightning passes to ground across an air gap it may *start* an arc which will be maintained by our dynamo with disastrous results. The entire theory of lightning arresters is too long to discuss in this volume, but the principles of protection from lightning are pretty well understood, and except in certain localities we can secure ample protection by using any one of a number of commercial forms of lightning arrester, provided we use *enough* of them and have them well distributed over our system of over-head conductors.

Lightning arresters are of course not needed in an isolated plant not having out-door conductors. Rule "a" calls for an arrester on each side of every circuit. This is necessary, for if arresters were placed only upon one side (that is attached to only one pole of our circuit) the lightning would have to go through our dynamo or our lamps or motors before it could get from the other pole to an arrester.

As regards Rule "b," everyone knows that lightning moves in mysterious ways, that while its action lasts but an instant it may leave destruction in its path; and when we consider that our dynamo may send a destructive arc to follow up the lightning, it is apparent that arresters should always be separated and as far as possible removed from combustible material, and should be placed where they can be readily inspected and repaired when injured by a discharge, as often happens. It is the judgment of experts who have most thoroughly investigated lightning discharges, as well as of engineers who have observed the effects of lightning, that it is better to steer the lightning to earth outside of the station than to invite it inside and then attempt to direct its movements. Whether we have lightning arresters on our switch board or not, we should have them on our *overhead line*, and if we can get arresters that will work all right on a pole, it would seem that a pole just outside the station was a better place than a switch board for the arresters to protect our machines and station.

Rule "c" requires lightning arresters to be connected with ground by two separate wires, and this is desirable as it is often very difficult to get a good earth contact (when you want one). A good connection to a grounded pipe in a building might invite unknown trouble, and a poor connection would be the means of leading the lightning into the building without giving it an adequate means of escape. In case the pipe should become disconnected from the earth, its use as an earth connection would simply lead the lightning into the building and turn it loose upon a network of pipes, leaving it to make its escape at its own convenience. This kind of thing has been done very often, and if the results have not always been disastrous, it has only been due to the element of chance, which seems to play such a large part in the movements of lightning. Rule "d" is called forth by the fact, as above stated, that a dynamo will maintain an arc which lightning has started. Such an arc would, of course, destroy the lightning arrester even if it did no other damage. There are many devices for either breaking the arc thus formed or for preventing an arc being formed, and these devices constitute the only essential points of difference between lightning arresters. The type of lightning arrester which is best adapted to any given plant depends upon the pressure and current of the dynamos and circuits and the kind of work to which the current is to be applied. We need only state here that there are upon the market satisfactory devices adapted to all conditions of practice.

CHAPTER IV.

CENTRAL STATIONS FOR LIGHT AND POWER. PART III.

TEXT OF CODE COVERED BY THIS CHAPTER. 7. TESTING:—*a*. All series and alternating circuits must be tested every two hours while in operation, to discover any leakage to earth, abnormal in view of the potential and method of operation. *b*. All multiple arc low potential systems (300 volts or less) must be provided with an indicating or detecting device, readily attachable, to afford easy means of testing where the station operates continuously. *c*. Data obtained from all tests must be preserved for examination by insurance inspectors.

These rules on testing to be applied at such places as may be designated by the association having jurisdiction.

8. MOTORS:—*a*. Must be wired under the same precautions as with a current of the same volume and potential for lighting. The motor and resistance-box must be protected by a double pole cut-out and controlled by a double pole switch, except in cases where one-quarter horse-power or less is used on low tension circuit a single pole switch will be accepted. *b*. Must be thoroughly insulated, mounted on filled dry wood, be raised at least eight inches above the surrounding floor, be provided with pans to prevent oil from soaking into the floor, and must be kept clean. *c*. Must be covered with a waterproof cover when not in use, and, if deemed necessary by the inspector, be inclosed in an *approved* case.

9. RESISTANCE BOXES:—*a*. Must be equipped with metal or other non-combustible frames. *b*. Must be placed on the switchboard, or at a distance of a foot from combustible material, or separated therefrom by a non-inflammable, non-absorptive, insulating material.

Testing.—We have thus far treated of methods of securing good insulation. Proper maintenance is just as important as proper installation. It is always difficult to maintain the insulation upon the circuits of a Central Station, especially where there are many and long circuits. We must always remember that a ground upon a wire of one polarity puts a strain upon the insulation of all the wires of opposite polarity. If a second ground comes upon a wire in a building, it may cause serious trouble, even if the first ground is out in the street. Rule "a" is not very specific, as it simply states that the circuit shall be "tested." This might mean a rough test, which would only *indicate* the presence of trouble. The insulation of the circuits should be *measured* frequently, and these measurements recorded. These measurements can be made while the circuits are in operation by using a suitable volt meter, or an instrument specially designed for that purpose.

Series Circuit.—If we attach one end of a wire to one brush or pole of a dynamo and the other end to the other pole, it will form what we call a circuit. If the dynamo is in motion, a current will flow through the wire. The strength of current will depend upon the electrical pressure or E. M. F. between the two poles of the dynamo, and upon the resistance of the wire (this resistance being determined by the size and length of the wire and the material of which it is made). If we cut this wire at any point, and bridge over the gap thus formed by inserting therein a lamp, our current will now flow through the lamp. If we cut the wire in a second place and insert there a second lamp, the current will flow through both lamps. We describe such an arrangement by saying that the lamps are connected in "*series.*" By making more cuts and inserting a lamp in each gap, we can connect up any number of lamps in series, and as the current always flows in a closed circuit, the same current will flow through each and all the lamps. This method of connection is commonly used for arc lamps. As each lamp offers some resistance to the flow of the circuit, we will increase the resistance of our total circuit or path every time that we add a lamp. The increased resistance will decrease our current unless at the same time we increase the pressure of our dynamo. For example, the current required to properly operate a two thousand candle power arc lamp, such as is commonly used in street lighting, is 10 amperes. It requires a pressure of 50 volts to send this current through one lamp. If now we insert a second lamp in series with the first, it will require an additional 50 volts, or a total pressure of 100 volts to send 10 amperes through both lamps. If we insert 10 lamps in the series, it will require 50 volts for each lamp, or a total of 500 volts to push 10 amperes through the entire series. It naturally follows, therefore, that if we wish to run a great many lamps in one series, we must have a very high pressure. The code regards anything over 300 volts as a high pressure, or "*high potential.*" As 300 volts will only operate a series of 6 arc lamps, nearly all arc lighting circuits come under the head of "high potential." It is common practice to install arc circuits of 50 lamps requiring a pressure of 2,500 volts, and it is not uncommon to install 100 light or 5,000 volt circuits.

Multiple Arc Circuits.—Suppose now we attach one end of one wire to the positive pole of our dynamo and one end of another wire to the negative pole of our dynamo, the other ends of the wires being free, and the wires insulated from one another. As our circuit is not completed, no current will flow from one wire to the other. If now we insert a lamp between the two wires, we will establish a circuit from one pole of the dynamo to the other through the lamp. A current will flow through one wire to the lamp, through the lamp, and back along the other wire to the opposite pole of the dynamo. The strength of the current will be determined by the resistance of our wire, and of our lamp; and as the resistance of our wire is in practice very small compared with that of our lamp, we may say that the current is determined by the pressure of the dynamo and the resistance of the lamp. If now we connect another lamp between our two wires, we have our circuit completed by two paths, and the current will flow through each of them. We say that the two lamps are connected in "*parallel*" or in "*multiple arc.*" We can in a similar manner connect any number of lamps between our two wires, thus forming any number of return paths. If each one of our lamps has the same resistance, the current will divide equally between them all. It is customary to connect up incandescent lamps in "multiple arc." The most common form of 16 c. p. incandescent lamp requires a current of about one-half an ampere to operate it properly, and to cause this current to pass through the lamp we require a pressure of 110 volts. If we have a pressure of 110 volts between two wires, and insert such a lamp, we will therefore get a current through the dynamo, wires and lamp of one-half an ampere. If we insert a second lamp, we will, if we still maintain our pressure at 110 volts between our wires, also get a current of one-half an ampere through the second lamp, so that our dynamo will send out a current of one ampere through the circuit, and this current will be divided equally between the two lamps. In the same way, if we attach any number, say 100, lamps between the two wires in "multiple arc," we will, if the pressure is held constant at 110 volts, get one-half an ampere through each lamp, so that our dynamo will be sending out a current of 50 amperes through the circuit, to be divided equally among the 100 lamps. We thus see that the two connections, "series" and "multiple arc," are diametrically opposite to one another. With one system (series) our current is the same for any number of lamps, but our pressure must be increased as the number of lamps is increased. In "multiple arc" system, however, the pressure of our dynamo remains practically the same, no matter how many lamps are in circuit, but each additional lamp calls for so much additional current. The system of lighting with the lamps in series is commonly called the "constant current" system, and the system of lighting with lamps in multiple arc is called a "constant potential" system. Since up to the present time the electric art has not produced a satisfactory commercial incandescent lamp that will stand a pressure of over 110 to 115 volts, current for incandescent lighting is usually distributed upon low potential circuits. Electric motors are almost universally operated upon multiple arc circuits, and at a pressure of either 110, 220 or 500 volts, 220 volts being the most common pressure, except for motors upon street cars, which are almost universally operated at 500 volts. We may apply our analogy of the flow of water to illustrate a series or multiple arc circuit in a number of ways. For example, suppose that we have a large number of small tanks, placed one directly above another. If we have a small hole in the bottom of each tank, so that the water will flow from each tank into the one below it, we will, upon pumping water into the top tank, have a current flowing down through all the tanks *in series.* If we connect our bottom tank to a reservoir, and pump the water from the reservoir up through a pipe into the top tank, we will have a fair illustration of the "series" system. Our pump corresponds to our dynamo; our pipe to our wire or conductor, and our tanks to our electric lamps. The higher we stack up our tanks, the greater must be the pressure of our pump to lift the same amount of water. Our water pressure corresponds to our volts, and the rate of flow of water corresponds to our amperes. Again, suppose that we have one large tank, with a great number of holes in the bottom; if now we pump water into this tank fast enough so that we maintain a *constant level* or head in the tank, we shall have a flow out of the tank which will depend upon the number and size of the holes. If our holes are all the same size and shape, we will get the same flow through any one hole as through each of the others, *i. e.*, the flow would be proportionate to the number of holes. If our tank is fed by a pump as before, the water being carried back into the tank through a pipe, we shall have a fair illustration of a "multiple arc" system. Our pump (dynamo) maintains a large rate of flow (amperes) at a constant pressure upon bottom of the tank of so many pounds to the square inch (volts).

Alternating Circuit.—Up to the present we have talked of electricity in the form of a current flowing, like water in a pipe, *in one direction.* We have, however, to consider in electricity what is called an *"Alternating Current," i. e.*, a current which flows in a wire first in one direction and then in the other direction. We can only use our water analogy by comparing this kind of current to what we would get provided we had a cylinder containing a piston and should connect the two ends of the cylinder to one another by a pipe. If now the cylinder and pipe are both full of water, we will get a flow in the pipe with each movement of the piston. If our piston moves back and forth, our current will first flow in one direction, then cease and then flow in the opposite direction. We do not, at this time, need to go further into a discussion of the nature of an "alternating current" than to give this simple analogy. The application of alternating current will be considered more fully when we come to that part of the code which considers "alternating systems." For the present we need only say that the alternating current is used extensively for incandescent lighting, and to a limited extent for operating arc lamps and motors. The object of using an alternating current for incandescent lamps is that it enables us to operate the lamps in multiple arc, at a great distance from our dynamo, with the use of much smaller conducting wires than would be required for the same number of lamps if a direct current were used. The higher the pressure or voltage at which we transmit electricity, the smaller will be our wire for a given distance of transmission, and a given loss of energy. For example, suppose we wish to transmit electricity for 1,000 sixteen-candle electric lamps a distance of one mile with a loss of only 10 per cent. of our power in overcoming the resistance of our conductors. If we undertake to run our dynamo at 120 volts, and supply direct current to our lamps at a pressure of 110 volts, our wire will be of enormous size, *i. e.*, over two inches in diameter. If we could transmit the same amount of electric energy at a pressure of 1,200 volts, instead of 120, we could, with the same loss of energy, use a wire of only $\frac{1}{100}$ the weight per foot, or a wire having a diameter of less than a quarter of an inch. As we said before, we cannot secure satisfactory incandescent lamps which will operate at a pressure of over about 110 or 115 volts. If, however, we should transmit our electricity at a high pressure, say 1,000 or 2,000 volts, and then transform it so that we could use it in our lamps, at a pressure of 110 volts, we would save immensely in the cost of our circuits. This we can do easily if we use an alternating current. The alternating current is therefore used to enable us to use *high pressures* on our *outside circuits*. As regards our Central Station, therefore, the alternating circuit is a "high potential" circuit. The code treats all series circuits and all alternating circuits (either series of multiple arc) as high potential circuits. Rule "b" refers to the use of what is commonly called a "ground detector." The most common form of this device consists of two or more incandescent lamps and a push button for making a momentary connection of the system to the earth. If a system of conductors is grounded (*i. e.*, poorly insulated from the earth), then as soon as we push the button the lamps will show an unequal brilliancy which indicates at once which pole of the circuit is grounded, and in a rough way shows whether the resistance of the ground contact is large or small. When a ground appears upon a low potential system while the circuits are in operation, it can usually be measured by an ordinary portable volt meter. When this cannot be done, the insulation should be measured immediately after shutting down the station. In any event the ground should be immediately located and promptly removed.

Motors.—Motors are subject to the same rules concerning installation and maintainance as dynamos. Rule "a" requires a double pole cut-out and a double pole switch. This simply means that every motor must have a switch by which an attendant can disconnect it completely from the circuit, and that it must be equipped with a cut-out or safety device, which will automatically open the circuit of the motor, thus cutting the current out of the motor if at any time the current becomes great enough to over-heat it. It is one of the peculiarities of an electric motor that a pressure which will send the proper amount of current through it when it is running at full speed, will, when the motor is just starting, or is moving slowly, send through it a current large enough to destroy its insulation. This can only be guarded against by inserting into the circuit a variable resistance or "rheostat," by means of which the current can be controlled until the motor has gotten its speed. The resistance box when used for this purpose is ordinarily called a "starting rheostat," or "starting box." The motor should always be started with all the resistance in circuit, and the resistance should be cut out gradually as the speed increases, until at full speed it is all out. As the resistance thrown in circuit for starting of motor is usually made of wire of such a size that it will become very hot if permanently left in the circuit, the resistance box should be equipped with a switch of such design that the resistance must always be all out of circuit, except while it is being gradually turned out. The switch should also be so designed that whenever the motor circuit is opened, it cannot again be closed except with the resistance all in circuit. Without such a switch, if a Central Station operating motor should shut down for a few moments and then start up again, there would be a liberal display of fire-works at every motor, unless there happened to be an attendant on hand to immediately turn the handle of the rheostat. An attendant is almost always on hand to watch a dynamo while in operation. It is customary, however, when small motors are operated, to simply have a man to inspect them occasionally, perhaps only a few times a day. It is therefore important that a motor should be installed even more carefully than the dynamo, and should be protected by every available safeguard.

CHAPTER V.

CLASS B, HIGH POTENTIAL SYSTEMS. PART I.

TEXT OF CODE COVERED BY THIS CHAPTER. CLASS B, HIGH POTENTIAL SYSTEMS, OVER 300 VOLTS:—Any circuit attached to any machine, or combination of machines, which develop over 300 volts difference of potential between any two wires, shall be considered as a high potential circuit and coming under that class, unless an approved transforming device is used, which cuts the difference of potential down to less than 300 volts.

10. OUTSIDE CONDUCTORS:—All outside, overhead conductors (including services): *a*. Must be covered with some *approved* insulating material, not easily abraded, firmly secured to properly insulated and substantially built supports, all tie wires having an insulation equal to that of the conductors they confine. (See Definitions.) *b*. Must be so placed that moisture cannot form a cross-connection between them, not less than a foot apart, and not in contact with any substance other than their insulating supports. *c*. Must be at least seven feet above the highest point of flat roofs, and at least one foot above the ridge of pitched roofs over which they pass or to which they are attached. *d*. Must be protected by *dead insulated guard irons* or *wires* from possibility of contact with other conducting wires or substances to which current may leak. Special precautions of this kind must be taken where sharp angles occur, or where any wires might possibly come in contact with electric light or power wires. *e*. Must be provided with petticoat insulators of glass or porcelain. Porcelain knobs or cleats and rubber hooks will not be approved. *f*. Must be so spliced or jointed as to be both mechanically and electrically secure without solder. The joints must then be soldered, to insure preservation, and covered with an insulation equal to

that on the conductors. (See Definitions). *g*. Telegraph, telephone and similar wires must not be placed on the same cross-arm with electric light or power wires.

11. SERVICE BLOCKS:—Must be covered over their entire surface with at least two coats of water proof paint.

12. INTERIOR CONDUCTORS. All Interior Conductors:—*a*. Must be covered where they enter buildings from outside terminal insulators to and through the walls, with extra waterproof insulation, and must have drip loops outside. The hole through which the conductor passes must be bushed with waterproof and non-combustible insulating tube, slanting upward toward the inside. The tube must be sealed with tape, thoroughly painted, and securing the tube to the wire. *b*. Must be arranged to enter and leave the building through a double contact service switch, which will effectually close the main circuit and disconnect the interior wires when it is turned "off." The switch must be so constructed that it shall be automatic in its action, not stopping between points when started, and prevent an arc between the points under all circumstances; it must indicate on inspection whether the current be "on" or "off," and be mounted in a non-combustible case, and kept free from moisture, and easy of access to police or firemen. So called "snap switches" shall not be used on high potential circuits. *c*. Must be always in plain sight, and never encased, except when *required* by the inspector. *d*. Must be covered in all cases with an *approved* non-combustible material that will adhere to the wire, not fray by friction, and bear a temperature of 150 degrees F. without softening. (See Definitions). *e*. Must be supported on glass or porcelain insulators, and kept rigidly at least eight inches from each other, except within the structure of lamps or on hanger boards, cut-out boxes, or the like, where less distance is necessary. *f*. Must be separated from contact with walls, floors, timbers or partitions through which they may pass by non-combustible insulating tube. *g*. Must be so spliced or joined as to be both mechanically and electrically secure without solder. They must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

DEFINITION of the word APPROVED as used in these rules, and notice of the approval of certain wires and materials, and the interpretation of certain rules.

RULE 10, SECTION *a*, AND RULE 12, SECTION *d*.—Insulation that will be *approved* for service wires must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one meghom per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water, with a current of 550 volts, and after three minutes' electrification.

WIRES:—The following list of wires have been tested and found to comply with the requirements for an approved insulation under Rule 10 *a*, Rule 12 *d*, and Rule 18 *a*: Acme, Ajax, Americanite, Bishop, Canvasite, Clark, Columbia, Crescent, Crown, Edison Machine, Globe, Grimshaw (white core), Habirshaw (red core), Kerite, National India Rubber Co. (N. I. R.), Okonite, Paranite, Raven Core, Safety Insulated (Requa white core, Safety black core), Salamander (rubber covered), Simplex (caoutchouc), United States (General Electric Co.) None of the above wires to be used unless protected with a substantial *braided* outer covering.

RULE 10, SECTION *f*. All joints must be soldered, even if made with the McIntyre or any other patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these Rules.

As we have stated, the high potential circuits in common use are, for the most part, either arc circuits, alternating current incandescent circuits, or electric railway circuits. Alternating current systems and street railway systems are separately treated in special sections of the code. The rules laid down in the part of the code under consideration apply particularly to the installation of *arc light* systems.

As we have stated in a previous chapter, arc lights are usually operated in series, and, as a consequence, an arc system is usually a high potential system. The pressure upon arc light circuits in common practice varies from 1,000 to 5,000 volts. From what we have already said about the nature of electricity, it is evident that the higher the pressure of a system the higher must be the resistance of our insulation to prevent leakage of current. Again, the higher the pressure, the greater the arc which will be maintained, in case the circuit is broken or interrupted. The higher the pressure the greater the hazard and the greater must be the care exercised to secure good insulation and to prevent the formation of an arc in the vicinity of combustible material.

A "service" is the name applied to the wires which connect an outside circuit (either overhead or underground) to the wires or conductors within a building. According to section "a" of Rule 10 and the definition applying to that section, a high grade of "*moisture proof*" or rubber-covered wire must be used on all outside high potential circuits. It is still the custom, however, to use upon pole lines what is called "weather proof" wire, or a wire covered with cotton braid saturated with a water proof compound or paint. As long as the weather proof wires stay in place upon their insulators and do not come in contact with other wires they are all right, as both the surrounding air and the glass supports are the best of insulators. Nearly all the arc circuits about the country are of weather-proof wire. If the construction is good, this class of work may be considered safe and satisfactory, where there are but few wires. In large cities, however, and in all places where arc wires cross and run near to other wires, such as telephone, telegraph and incandescent wires, the insulation should be the best that can be secured. Overhead wires are fastened to their supporting insulators by short pieces of wire called tie wires. As tie wires are twisted tightly about the conducting wire, it is required that the tie wires themselves shall be of insulated wire. A bare tie wire easily cuts through the covering of our conductor, and thus destroys our insulation at the very point where it is most needed. The distance between wires is determined by the span or distance between poles and the space available, but as a rule the insulators are supported upon standard cross-arms, the pins supporting the insulators being one foot apart.

When any two conductors come into metallic connection with one another they are said to be "crossed" with one another, and the contact is called a "*cross.*" Guard irons or wires are spoken of in the code as if there were two devices for doing the same thing. This is slightly misleading, as *guard wires* are usually stretched over live conductors to prevent other wires from falling upon them, while guard *irons* are most often used to prevent conductors from falling down in case they should become detached from their supporting insulators.

The weak points in the insulation of wires on a pole line are where the wires are tied to the insulators; and as the best of insulation deteriorates with age and is liable to mechanical injury, we must depend for our insulation chiefly upon our insulators.

The ordinary green glass insulator which we see screwed upon a pin driven into a cross arm is a "petticoat" insulator. These insulators extend down below the point where the pin screws in, forming an umbrella or "petticoat," thus keeping the top of the pin and the bottom of the insulator dry even when it rains or snows. When freshly made, a good "twist" or "Western Union" joint, made by twisting the wires tightly together, forms a perfectly good connection both electrically and mechanically, if carefully made; but such a joint will work loose from swinging or from expansion, the surface of the wire will corrode and the joint will offer a high resistance to the passage of the current. Solder should therefore be used on all joints; for whereever there is resistance, energy is lost and heat is generated. The McIntyre connector referred to in the definition explanatory of section "f" is a patent device for joining wires and making a tight joint quickly; but with a joint thus made, as with any other joint, the contact depends upon the skill and care of the man making the joint and solder is the best thing to secure a sure and permanent joint

Interior Conductors.—At all points where wires enter buildings, special pains must be taken to secure good insulation, as the wire at these points is liable to have its insulation mechanically injured unless it is firmly secured in place; and again, where a wire goes through a wall it is pretty sure to come in contact with moisture unless it is specially protected. Where the wires go through a *wooden* wall, it is of course impossible to keep them far away from the wood, and unless they are surrounded by a non-inflammable insulation, there is always a hazard. Tubes for surrounding high potential wires should be of glass, porcelain or vitrified earthen ware.

A "drip loop," as its name indicates, is a downward bend in the wire just outside the building. By allowing our insulating tube to project through the wall and to slant upward toward the inside, and by giving the water a chance to drip off a sharp bend in the wire outside the building, we can effectually prevent any water from following the wire into the building. As we have said, nearly all the high pressure wires which enter buildings are arc wires.

Section "b" describes an arc light switch. As arc lights are usually operated in series, if we cut out a light or a number of lights with a switch we will open our circuit and thus put out all the lights upon the circuit, unless, at the same time, we close the circuit through some other path. An arc light switch is, therefore, so designed that it provides a new path for the current before it opens the circuit to the lamps which it controls. A "snap" switch is the name applied to the small round switch such as is commonly used for controlling small groups of incandescent lamps. These switches are not so constructed as to break a high potential current without arcing. As they are generally made, an arc of this kind would destroy the switch and endanger any adjacent wood work. A switch is rendered "automatic" in its action by so designing it that, when its handle is moved, a spring throws the switch so as to either close or to completely open the circuit. Section "d" requires that high pressure wires must be run in sight, *i. e.*, what is known as "open wiring" must be used. It is a general rule that open wiring is always safer than concealed wiring, except where it is necessary to cover the wires to secure mechanical protection. For interior conductors nothing except moisture proof wire should ever be used. A "*megohm*" (referred to in the definition of Rule 10, section "a"), is equal to 1,000,000 ohms.

The insulation resistance of a wire is usually tested by immersing the wire in a tank of water and measuring the resistance between the water and the ends of the wire, which are kept dry and well out of the water. The greater the length of a wire the greater will be the leakage, or what amounts to the same thing, the less will be the insulation resistance; so that the code properly requires a certain insulation resistance *per mile*. Not only should none but approved wires be used, but we should bear in mind that all of the wires "approved" are not of the same grade. In fact, the list in the code includes, in some cases, more than one grade of wire made by the same manufacturer. Section "e" is important; but while it is important that the wires shall be separated a proper distance, it is still more important that the wires shall be so supported that they will always be held rigidly apart. Section "f" (which applies also to wires of *low* potential), is a very important requirement. If sections "e" and "f" are strictly observed, there will be no danger of heat being conveyed to wood work, even though the wires become excessively hot, unless the insulation of the wire itself takes fire. The first requirement of section "g" is for protection against poor workmanship. The clause concerning insulation of joints has already been discussed. Although it calls for what is practically an impossibility, still this section is an important one, as it directs our attention to the fact that *all* joints should be avoided as far as is possible (except when they come in the air between insulators), and when they cannot be avoided, they should be just as good as material and skill can make them.

CHAPTER VI.

HIGH POTENTIAL SYSTEMS. PART II.

TEXT OF CODE COVERED BY THIS CHAPTER. LAMPS AND OTHER DEVICES. 13. ARC LAMPS—In every case:—*a*. Must be carefully insulated from inflammable material. *b*. Must be provided at all times with a glass globe surrounding the arc, securely fastened upon a closed base. No broken or cracked globes to be used. *c*. Must be provided with an *approved* hand switch, also an automatic switch, that will shunt the current around the carbons should they fail to feed properly. *d*. Must be provided with reliable stops to prevent carbons from falling out in case the clamps become loose. (See Definitions.) *e*. Must be carefully insulated from the circuit in all their exposed parts. *f*. Must be provided with a wire netting around the globe, and an *approved* spark arrester above to prevent escape of sparks, melted copper or carbon, where readily inflammable material is in the vicinity of the lamps. It is recommended that plain carbons, not copper-plated, be used for lamps in such places. (See Definitions.) *g*. Hanger-boards must be so constructed that all wires and current-carrying devices thereon shall be exposed to view and thoroughly insulated by being mounted on a waterproof, non-combustible substance. All switches attached to the same must be so constructed that they shall be automatic in their action, not stopping between points when started, and preventing an arc between points under all circumstances. *h*. Where hanger boards are not used, lamps to be hung from insulated supports other than their conductors.

14. INCANDESCENT LAMPS IN SERIES CIRCUITS HAVING A MAXIMUM POTENTIAL OF 300 VOLTS OR OVER:—*a*. Must be governed by the same rules as for arc lights, and each series lamp provided

with an *approved* hand spring switch and automatic cut-out. *b.* Must have each lamp suspended from a hanger board by means of a rigid tube. *c.* No electro magnetic device for switches and no system of multiple series or series multiple lighting will be approved. *d.* Under no circumstances can series lamps be attached to gas fixtures.

DEFINITIONS.—RULE 13. ARC LAMPS:—Section *c.* The hand switch to be *approved*, if placed anywhere except on the lamp itself, must comply with requirements for switches on hanger boards as laid down in Section "g" of Rule 13. Section *f.* An *approved* spark arrester is one which will so close the upper orifice of the globe that it will be impossible for any sparks thrown off by the carbon to escape.

LAMPS AND OTHER DEVICES.

Arc Lamps.—The arc of an arc lamp, like any electric arc, consists of a flame which gives a most intense heat. The arc is maintained between the ends of two rods or pencils of carbon, commonly called "carbons." The arc gradually burns away the carbons, so that there is a constant combustion going on all the time that the lamp is burning. As the arc is a source of heat, it is evident that the lamp must be so protected that no inflammable substance can ever come in contact with the arc. If the arc is not protected from a draught, or if the carbons are not perfectly uniform in composition, sparks will be given off from the burning carbon. Again, the carbons become white hot on the ends for some distance from the arc; so that if a carbon should break or get loose and fall from its holder, it would readily ignite any inflammable substance that might be below the lamp. The use of a glass globe surrounding the arc is therefore absolutely essential, to prevent the possibility of fire from sparks or falling carbons, whenever a lamp is burned anywhere near combustible material. Since a globe is necessary, it is evident that it is necessary that the globe shall not be broken, and that a globe should be discarded as soon as it becomes cracked. A white or "opal" globe is useful for toning down and diffusing the light of an arc lamp, and any globe serves to protect the arc from wind or draughts which would interfere with the steadiness of the light; and very often people overlook the fact that the globe is still *more* useful in securing *safety*. We have seen that in arc lighting the lamps are usually connected "in series," and that the dynamo maintains a *constant current* in the circuit. A circuit of 2,000 candle power lamps, for example, will always carry a current of about 10 amperes. If now, while the current is kept constant, we join any two points of the circuit by a wire or conductor, we shall form a second path for the current between these points. The current will divide between the two paths. We say that the current has been "shunted" out of the first path or conductor, and we call the second conducting path a "*shunt.*" When a shunt is placed upon a portion of a circuit, the current will divide between the circuit and the shunt, according to their relative resistances. Whichever path has the higher resistance, will have the smaller current. If the resistance of the shunt is only a small fraction of the resistance of the original path, the current will practically all flow through the shunt. If, therefore, we wish to cut the current out of an arc light (in a series circuit), we have only to connect the two points where the current enters and where it leaves the lamp by a low resistance shunt. This is done in practice by connecting the ends of the wires leading to and from the lamp to the two sides of a switch, so that, upon closing the switch, the current will flow through the low resistance path presented by the switch, instead of through the lamp, which has a comparatively enormous resistance. An arc lamp is quite a complicated piece of mechanism. As the carbons are actually burned away, the arc in a lamp would gradually grow longer, until it got so long that it would break, if the carbons were rigidly fixed in position. An arc lamp is therefore provided with a feeding device. By means of this device, as fast as the carbons are burned away, they are automatically fed toward one another, so that they are always separated by about the same distance. If the feeding device should fail to work properly, the arc would grow longer and longer, until at last it would break and the current would go through the fine wires in the lamp, burning off its insulation and maintaining a fire until it had opened the circuit.

To prevent such an occurrence, the code requires in Rule "c" that the lamp shall be provided with an automatic switch in addition to the hand switch. The hand switch is used to shunt the current around the two terminals where the wires are joined to the lamp, thus cutting the current out of the lamp altogether. The automatic switch (which is a part of the lamp mechanism) is used to shunt the current around the gap formed between the carbons whenever the arc is broken and not immediately re-established. The automatic switch is essentially a safety device. Rule "d" refers to the proper design of the lamp itself. Some old style lamps were so constructed that if a lower carbon became loose, it could fall out of the lamp. The danger due to such construction is evident. Rule "e" should be observed for protection against fire, and also to prevent a hazard to life. Indirectly a hazard to life is a hazard to property; for if there is danger to life in handling an electric device or machine, the probability is that the machine or device will not receive proper care and attention, and almost any electrical apparatus which is not kept clean and in good working order is liable to become a source of danger. Rule "f" is one that should be rigidly enforced. An arc lamp should always be completely enclosed, when anywhere near combustible material. The object of a *wire netting* about a globe is to prevent a globe from falling to pieces in the event of its becoming cracked. Experience has often demonstrated the fact that a globe open at the top is not sufficient protection against the escape of sparks. Arc light carbons are often covered (by plating) with a thin coating of copper. Under certain conditions, coated carbons give better results; but the coating may increase the breakage of globes; especially if the coating is unnecessarily thick, as is sometimes the case. If a lamp is not properly "trimmed," that is to say, if the carbons are not of the right length or are not properly adjusted, the arc will sometimes consume the entire lower carbon and a part of the lower clamp or carbon holder, before it is automatically interrupted. This sort of an accident is liable to break the globe. Naturally, any hot carbon or molten metal that can break a globe may cause combustion after a globe is broken.

A "*hanger board*," like a "switch board," was originally a veritable *board*. The ordinary form of hanger board consisted of a small board from which the lamp was suspended when used for inside lighting. The board carried a switch and metal connectors or "binding posts," to which the wires of the circuit and the wires of the lamp were connected. The hanger board was generally screwed or nailed directly to the ceiling. These hanger boards proved to be a danger point, and many a fire was caused in them by poor contacts and moisture. In selling a plant, the hanger boards were generally included in the price of the lamps and dynamo, so that the manufacturers vied with one another in trying to see who could produce the cheapest board. It is surprising to see how well they succeeded. A ceiling is a bad place for any electrical device, and it has at last become apparent that hanger boards must be *fireproof* the same as other switch boards and switches. The only suitable materials at present applied to their construction are marble, slate and porcelain. It has in the past been common practice to support lamps by hanging them from the two conducting wires. These wires are always more than strong enough to support the weight of a lamp; and at first thought it seems as if the use of another suspending wire detracted from the appearance of the installation and was a waste of labor and material.

This kind of construction, although neat in appearance, is not the safest. If a supporting conducting wire becomes loosened from its connection to the lamp so that the weight of the lamp pulls it away from the wire, an arc will be formed between the wire and the connector on the lamp, and this arc may be long and destructive. Such an arc will throw off melted copper and create the worst kind of a hazard.

Incandescent Lamps on Series, High Potential, Circuits.—Our readers are doubtless all familiar with the incandescent lamp; but it may not be out of place to call attention to the distinction between an arc and an incandescent lamp. While the ends of the carbons in an arc lamp become incandescent or white-hot, this incandescence is not the principal source of its light. Nearly all the light is given off by the arc or flame. The arc is accompanied by combustion, the carbons being burned up as effectually as coal in a stove, and so rapidly that they last but a few hours. In an incandescent lamp, on the other hand, there is no combustion. We have found that in any conductor carrying current, energy is absorbed by something analogous to friction. This energy is transformed into heat which raises the temperature of the conductor. The greater the resistance of the conductor and the greater the current, the greater will be the heat generated in the conductor. If we take a thin copper wire we can readily heat it red hot with a few amperes. With a little more current it is heated white hot or incandescent. It now becomes a source of light. If we make our conductor of some material which (unlike copper) is a poor conductor, a very small current will suffice to heat it up to incandescence. The loop or "filament" in an incandescent lamp, is such a thin high resistance conductor. The filament is made of carbon, a material which has a high resistance and which becomes white hot at comparatively low temperature. The light is given off wholly by the incandescence of the filament. There is no combustion, for combustion would destroy the filament. Combustion is prevented by placing the filament in a hermetically sealed glass chamber from which the air has been exhausted so as to leave an almost perfect vacuum. Incandescent lamps are, as we have already said, usually operated "in multiple" and upon low potential circuits. There are many reasons for this. The operating of incandescent lamps in series, upon a large scale presents many engineering difficulties. While arc lamps are handled almost exclusively by men employed in lighting stations or plants, incandescent lamps are handled by people who could not with safety to themselves handle any device using a high potential current. Again incandescent lamps are used in many places where it would be practically impossible to prevent their causing a great hazard, if operated upon a high potential circuit. There are, however, a few special cases where it is desirable to operate incandescent lamps in this manner; as, for example, in street lighting and where the operating of a few incandescent lamps on an arc circuit will save the installation of expensive circuits or an extra dynamo. In such cases we can secure safety by following as closely as possible the rules governing the installation of arc light circuits.

Multiple Series,—Series Multiple.——These terms will be most easily understood from examples of their application in practice.

The most common form of 16-candle power incandescent lamp requires a current of about ½ an ampere. If we connect 20 of such lamps in parallel or multiple with one another the group will of course take a current of about 10 amperes. We can if we wish supply these lamps with their proper current by inserting the group into an arc light circuit which is carrying 10 amperes. If we connect up a number of groups in this manner, the lamps in one group being in multiple with one another, and the groups being in series with one another, we say that the lamps are connected in multiple series.

Again the ordinary incandescent lamp is operated at a pressure of about 110 volts. If we connect five of such lamps in series we must have a pressure of 550 volts to have them burn properly. We can burn the lamps by connecting the series between the two wires of a 550 volt multiple arc system, such as is used for operating street railway motors. We can thus connect up any number of series in multiple with one another and we describe the arrangement by saying that the lamps are connected in *series multiple.* The meaning of these terms may be easily remembered by noting that multiple series means *multiples in series*, and series multiple *series in multiple.* The *first word* applies to the connection of the *individuals* and the *second* to the arrangement of the *groups.* The method and devices used for controlling and protecting lamps connected in series or in multiple, or for preventing their creating a hazard, do not apply to their use in multiple series or series multiple. The complicated devices which have in the past been applied to such systems, for the purpose of securing good service and safety, have themselves been sources of annoyance and danger. The use of these systems is therefore forbidden. This prohibition however does not cause any hardship, as there are now many better and more simple ways of securing all the advantages that were sought by their use. The first clause of section "c" is undoubtedly aimed at the use of any "ingenious" and complicated device introduced to do something that can be done more simply and safely by hand. The form of incandescent lamp adapted to series lighting requires a low voltage, but takes a current of several amperes. It is not possible to protect lamps in series by the simple safety devices, such as are used on lamps when connected in multiple; and on a series system, an arc which might be set up by defective insulation in the fixture, would probably not be extinguished until it had burned itself out. In so doing, it might at the same time easily burn a hole or two in the gas pipe. A study of the devices used in ordinary incandescent light construction will show how necessary are sections "c" and "d" of Rule 14.

CHAPTER VII.

CLASS C, LOW POTENTIAL SYSTEMS. PART I.

TEXT OF CODE COVERED BY THIS CHAPTER. CLASS C, LOW POTENTIAL SYSTEMS, 300 VOLTS OR LESS. OUTSIDE CONDUCTORS. 15. OUTSIDE OVERHEAD CONDUCTORS:—*a*. Must be erected in accordance with the rules for high potential conductors. *b*. Must be separated not less than 12 inches, and be provided with an *approved* fusible cut-out, that will cut off the entire current as near as possible to the entrance to the building and inside the walls.

RULE 15. OUTSIDE OVERHEAD CONDUCTORS:—Section *b*. An *approved* fusible cut-out must comply with the sections of Rules 23 and 24, describing fuses and cut-outs. The cut-out required by this section must be placed so as to protect the switch required by Rule 17.

Outside Conductors.—Low potential systems include circuits for supplying incandescent lamps and power at short distances. Incandescent lamps on direct current systems are usually operated at 110 volts. On alternating current systems they are operated at either about 50 or about 100 volts. It is becoming common practice to operate arc lamps, two in series, upon the same system of conductors as 110 volt incandescent lamps. The highest pressure in common use in plants that come under the head of low potential systems is about 220 volts. Many central stations operate 110 volt lamps upon what is called a "*three-wire system*," to distinguish it from an ordinary multiple arc or "two-wire system" and from "multiple series" or "series multiple" systems.

The three-wire system is rather difficult to understand from a brief description unaccompanied by a diagram. The object of using a three-wire system is to save copper. By its use we can operate the same number of lamps, without greater loss of energy, upon a much smaller wire than would be required for a two-wire system. Suppose that we connect the lamps of a plant in two equal groups, each group having its lamps connected in multiple arc and each group having its own dynamo. If, now, we connect the two groups in series with one another throughout, or, what is the same thing, use a common wire for the positive of one group and the negative of the other group, we shall have a three-wire system. The wire common to both groups we call the neutral wire. The other two wires are called the positive and negative wires, respectively, or, when spoken of together, they are called simply the outside wires. By making a diagram of the above arrangement, the reader will see that we have a voltage of 220 volts between the two outside wires of a three-wire system using 110 volt lamps. This system is used in most of the direct current central stations in this country. In operating motors from a three-wire station, they are usually designed to operate at 220 volts, and are connected in between the two outside wires. This practice has led to the common use of 220 volt motors, so that this voltage is quite generally used for operating stationary motors, where they are not too far from the generators. By far the greater proportion of all low potential circuits are incandescent lighting circuits. Arc lamps and motors, where used on low voltages, are usually connected to incandescent lighting systems.

One would naturally expect, from what we have said about the importance of high insulation and the difficulty of securing it on high pressure systems, that it would be a comparatively simple thing to secure safety on a low potential system, and that the rules concerning the installation of low potential circuits would be few and brief. On the contrary, we find the greater portion of the code devoted to this class of work. The reason for this is, that high pressure arc circuits are generally located out in the street; or, if the lamps are inside, the wires are run exposed upon glass or porcelain knobs, where they can be readily inspected. In incandescent lighting, on the other hand, the lamps are used mostly for inside lighting, and they are placed in every conceivable kind of place and position. Again, the incandescent lamps call for a multiplicity of wires, and these wires must usually be concealed in some manner to prevent their marring the appearance of interiors. Safety, under these trying conditions, requires the use of a high grade of insulation upon our wires, careful and intelligent workmanship, and well designed appliances in the line of fixtures, switches, cut-outs, etc. While high voltage places a great strain upon insulation, powerful currents, such as we have upon circuits carrying many incandescent lights, represent an immense amount of energy; and the fire hazard of electricity is simply the danger of transforming the energy of an electric current into heat *in the wrong place*. The code applies the same rules to outside conductors of low as of high potential systems. It is related that the laws of Draco imposed the same penalty for the punishment of all crimes, *i. e.*, death. This severity was justified by the argument that the least of crimes deserved death, and that there was no more severe penalty which could be applied to the punishment of the greater crimes. Some such logic as this was doubtless used by those who framed the rules concerning outside overhead conductors. From an insurance man's standpoint, about all that can be said concerning the insulation of outside conductors, either overhead or underground, is that the better the insulation outside, the less will be the danger of fire from any accident or defect on inside circuits (excepting, perhaps, danger from lightning). If we so protect our circuits that no trouble on the outside can cause a hazard inside a building, and then require as good insulation on outside conductors as can be secured without an expense that would impose an unreasonable hardship upon the central station company, we shall be following what is at present the best practice. The one thing most important to observe is that low potential wires which enter a building must be protected from any possible contact with any high potential wires outside the building, as any such contact creates a fire hazard and is a menace to human life. Rule 15 brings up for the first time the "fusible cut-out." As in series arc work we protect our lamp by two devices—first, a switch by which the current is cut out of the lamp by hand, and, second, an automatic device to automatically cut the current out of the lamp in case of trouble; so, in incandescent lighting, we must protect our circuits, first, by hand switches, and, second, by automatic cut-outs which interrupt, and thus cut the current out of, the circuits to be protected.

We must always aim to keep clear in our minds the difference between arc and incandescent work. While both systems require good insulation and hand and automatic control, we find, at every turn, that their conditions and requirements are diametrically opposite in many respects. In *arc* work we have *series* connections; in *incandescent* work we have *multiple* connections. In *arc* work we have a *constant current* and a pressure varying with the number of lamps. In *incandescent* work we have a *constant pressure* and a current varying with the number of lamps. In *arc* work we have *small currents* and often very *high pressures.* In *incandescent* work we have *low pressures* and often *enormous currents.* Naturally enough, our automatic protecting devices on arc systems protect against excesses of pressure, and on incandescent systems against excesses of current. The current on the arc system and the pressure on the incandescent system are regulated at the dynamo. We can always keep ourselves from confusing the two systems by remembering that an *arc* is a *constant current,* and an *incandescent* a *constant pressure* system. To cut off a lamp on a series system, we shunt the current around the lamp with a switch. In a multiple arc system we cut off the lamp by disconnecting it from the circuit, *i. e.*, by introducing an opening into one or both conductors leading to the lamp. In each system the cut-out performs the same function as a switch. It cuts out an arc lamp by *shunting* around the lamp, and an incandescent system by *opening* the circuit to the lamp.

The cut-out in an arc system is a part of the lamp itself, and its design need not be considered here. In incandescent systems, however, the cut-outs are separate devices, and they are of the kind known as "*fusible* cut-outs." There are many kinds of these cut-outs, some good and some very bad. Some forms have been used which were so poor in design that they themselves created a hazard. It is, therefore, of the utmost importance that we shall thoroughly understand the principle of the fusible cut-out and what distinguishes a good one from a poor one. As we have already seen, the passage of a current through a wire heats the wire. If the current is strong and the wire is of small diameter, the wire will get very hot. It is the function of the fusible cut-out to prevent the wire of a circuit from receiving a current strong enough to overheat it. This is accomplished by inserting into the circuit a short piece of comparatively fine wire (usually of some material which will melt at a low temperature), so that an excess of current will melt or "fuse" this piece of wire before it has time to heat the circuit wire or conductor to a temperature that could ignite inflammable material or even injure the insulating covering of the conductor. A device by which such a fusible wire is inserted into one or both wires of a circuit is called a "fusible cut-out."

When the device inserts a fusible wire or "fuse" into *both* wires of a circuit, it is called a "*double-pole*" cut-out, just as a switch which opens both wires, is called a double-pole switch. In order that a fusible cut-out may protect a circuit to a lamp or a group of lamps, it must be so placed that no current can flow to the circuit except through the cut-out. If of correct design and size, it will then protect all conductors *beyond it.* The code devotes considerable space to statements as to how cut-outs must be designed and installed. A fusible cut-out only protects the conductors beyond it, so that if we wish to protect *all* the wires in a building from any excessive flow of current from the outside, we must place a cut-out as near as possible to the point where the conductors enter the building, as specified in Rule 15, section "b."

CHAPTER VIII.

CLASS C, LOW POTENTIAL SYSTEMS. PART II.

TEXT OF THE CODE COVERED BY THIS CHAPTER. 16. UNDERGROUND CONDUCTORS:—*a*. Must be protected against moisture and mechanical injury, and be removed at least two feet from combustible material when brought into a building, but not connected with the interior conductors. *b*. Must have a switch and a cut-out for each wire between the underground conductors and the interior wiring when the two parts of the wiring are connected. These switches and fuses must be placed as near as possible to the end of the underground conduit, and connected therewith by specially insulated conductors, kept apart not less than two and one-half inches. (See Definitions.) *c*. Must not be so arranged as to shunt the current through a building around any catch-box.

INSIDE WIRING. GENERAL RULES:—17. At the entrance of every building there shall be an *approved* switch placed in the service conductors by which the current may be entirely cut off. (See Definitions.)

18. CONDUCTORS:—*a*. Must have an *approved* insulating covering, and must not be of sizes smaller than No. 14 B. & S., No. 16 B. W. G., or No. 4 E. S. G., except that in conduit installed under Rule 22, No. 16 B. & S., No. 18 B. W. G., or No. 2 E. S. G. may be used. (See Definitions.) *b*. Must be protected when passing through FLOORS; or through walls, partitions, timbers, etc., in places liable to be exposed to dampness by waterproof, non-combustible, insulating tubes, such as glass or porcelain. Must be protected when passing through walls, partitions, timbers, etc., in places not liable to be exposed to dampness by *approved* insulating bushings specially made for the purpose. (See Definitions.) *c*. Must be kept free from contact with gas,

water or other metallic piping, or any other conductors or conducting material which they may cross (except high potential conductors) by some continuous and firmly fixed non-conductor creating a separation of at least one inch. Deviations from this rule may sometimes be allowed by special permission. *d.* Must be so placed in crossing high potential conductors that there shall be a space of at least one foot at all points between the high and low tension conductors. *e.* Must be so placed in wet places that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run *over* all pipes upon which condensed moisture is likely to gather, or which by leaking might cause trouble on a circuit. *f.* Must be so spliced or joined as to be both mechanically and electrically secure without solder. They must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors. (See Definitions.)

DEFINITIONS. RULE 16. UNDERGROUND CONDUCTORS:—Section *b.* The cut-out required by this section must be placed so as to protect the switch. RULE 17:—The switch required by this rule to be *approved* must be double pole, must plainly indicate whether the current is "on" or "off," and must comply with sections *a*, *c*, *d* and *e* of Rule 26 relating to switches. RULE 18. CONDUCTORS:—Section *a.* In so-called "concealed" wiring, moulding and conduit work, and in places liable to be exposed to dampness, the insulating covering of the wire, to be *approved*, must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water, with a current of 550 volts, and after three minutes' electrification. For work which is *entirely* exposed to view throughout the whole interior circuits, and not liable to be exposed to dampness, a wire with an insulating covering that will not support combustion, will resist abrasion, is at least $\frac{1}{16}$ of an inch in thickness, and thoroughly impregnated with a moisture repellant, will be *approved.* Section *b*, second paragraph. Except for *floors* and for places liable to be exposed to dampness, glass, porcelain, *metal-sheathed interior conduit* and vulca tube, when made especially for bushings, will be *approved. The two last named will not be approved if cut from the usual lengths of tube made for conduit work, nor when made without a head or flange on one end.* Section *f.* All joints must be soldered, even if made with the McIntyre or any other patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

Underground Conductors.—Section "a" requires that special care shall be taken in installing wires at points where they enter a building. We have already called attention to the fact that at all points where wires pass through walls special care should be exercised. It is almost impossible to maintain the same standard of insulation in a large system of out-door conductors (especially if they are underground) that we can maintain on a system of conductors confined to one building. We should, therefore, when we are compelled to bring outside conductors into a building, use the best of materials and workmanship, as called for in section "a," and we should locate the safety devices which separate the outside from the inside conductors, as near as possible to the point where the outside wires enter the building, as required in section "b." The safety devices required in all cases are a hand switch and an automatic cut-out. These devices have been described in a preceding chapter. The cut-out is to protect the inside wiring from any excess of current that might overheat the conductors, and the switch is for the purpose of disconnecting the wiring in the building from the street conductors. This switch is a necessary protection for use in case of a fire in the building or of any serious trouble with the inside circuits. Ordinarily this switch is seldom or never used except to disconnect the inside wiring from the central station conductors for the purpose of testing its insulation. Such a switch should always be installed if only for convenience in testing, as nothing is more essential for the safe and proper maintenance of any system of conductors than that it shall be installed in such a manner that it can at all times be easily and quickly tested. The object of locating the switch as required in the definition under section "b" is apparent when we consider that a central station is a source of electrical energy of such a capacity that it can for a short time send out an almost unlimited supply. The station can readily put out current enough to destroy any switch that would be used in a building, so that we must consider the switch as a part of the inside system to be protected by our cut-out.

Rule "c" refers to a "catch-box." This name is applied to an underground chamber located in the street and containing the "safety catches" or fuses which protect the street mains from an excessive current. These catches connect the various sections of the conductors. If there is any excessive rush of current to any section of the street conductors it is the function of these "catches" to melt and interrupt the flow. If, however, there is a shunt, or another path in multiple with the catch, this path may take so much of the current that the catch will not melt; and even if it does melt the current will not be interrupted but will still flow through the shunt circuit. If, therefore, the wiring of a building is so installed that it is connected as a shunt around such safety catches, this wiring may at any time receive an unknown amount of current, regardless of the number of lamps or motors that may be connected to it. While the inside wiring *should* be protected from damage by the switches and cut-outs above referred to, still such an arrangement of circuits ought never to be allowed, as it will create an extraordinary hazard, if the safety devices are not absolutely certain in their action, and moreover such an arrangement is absolutely needless. It could never be of any advantage and would be an annoyance even if it were not a source of danger.

Inside Wiring. General Rules.—The switch referred to in this section, is the same device that is required by Rule 16. The design of the switch depends upon the system used and upon the number of amperes that it has to carry. The essential points of its design are described under Rule 26.

Conductors.—"*Approved*" insulation is described by the definition in the code. The list of wires referred to is a list of the best makes of wires having what is known as a moisture proof insulation. This insulation is made of a composition of which the chief ingredient is supposed to be pure rubber. The insulations, however, vary greatly in composition, and the fact that a wire is in the list of "approved" wires in the code, is no guarantee that its insulation will prove satisfactory under all the conditions to which a conductor may be subjected. Some of the wires specified are of a much higher grade than others. A wire which, under ordinary circumstances, will hold up its insulation all right, may under some conditions prove worthless; and another wire which will hold up under these conditions, may prove worthless under unfavorable conditions of another kind. We must always select our insulation according to the conditions. In selecting a wire we must consider the manner in which it is to be installed and the agents by which its insulation may be attacked, *i. e.*, whether or not it is to be exposed to extreme heat or to contact with oils or chemicals; and if there is a probability of exposure to chemical action we should consider the nature of the chemicals as the same chemicals act quite differently upon different insulating substances. In case of doubt we should use the wire which we find has given the best results in general use, and which has stood the test of time.

As regards the *size* of wires to be used, this is determined as far as safety is concerned, by the table of "safe carrying capacities," given later in the code.

Wires are commonly measured in one of the following gauges: Brown and Sharp, Birmingham Wire Gauge or Edison Standard Gauge. The abbreviations are used in the code. The code allows the use of no wire smaller than No. 14 B. & S. gauge or its equivalent in other gauges (except in special cases). While a number 16 B. & S. wire will carry 6 amperes more safely than a number 14 will carry 12 amperes as far as overheating is concerned, still it is not good practice to ever use a wire smaller than number 14 B. & S. gauge in any place where it can be subjected to a mechanical strain. A wire smaller than this will be stretched considerably if it is pulled up tight, and if the wire stretches, the insulation must also stretch and thus become subjected to a permanent strain. Under such a strain, any insulation must eventually give way and much "rubber" covering will soon dry out and become comparatively brittle. Again, it is difficult to make a good twist joint in a very small wire without breaking or cracking the wire, especially when a joint is made between it and another wire of a larger size. It is very questionable if it is good engineering to use a number 16 B. & S. wire in a conduit. The only place where it seems excusable to use a small wire is in a fixture carrying a few lights or in a drop-cord for suspending one light.

The requirements of section "b" call for an extra insulation at what we have found to be the weak points of a system of inside conductors. The tubes or bushings also serve as a mechanical protection. In order to carry out the requirements strictly it is necessary to use insulating bushings at *all* points where wires pass through wood-work; not only at partitions and floors but at all places where wires are run through holes in timbers or studding. Such construction not only increases the insulation but also allows us to maintain a pretty good insulation even if the insulating covering of our wire deteriorates; and what is perhaps still more important, it prevents the wood-work from becoming charred or ignited even if the wires become excessively overheated. If glass or porcelain tubes are used we have our wire installed in the ideal manner, *i. e.*, we have it treated as if it were bare wire.

At the present price of porcelain bushings, it is no hardship upon the owner to insist upon the use of moisture and fire-proof bushings for *all* holes in woodwork. As to what places are "liable to be exposed to dampness," it is safe to assume that we will get dampness at any place where there are wires and where we do not want it. As dampness may result from defective plumbing or any accidental overflow of water, it is safe to say that wires in any building with water pipes in it are liable to be exposed to dampness. The "Interior Conduit" referred to in the definition is the trade name of a tubing made of paper, impregnated with a waterproof compound. "Vulca Duct" is the trade name of another tubing; the material of which it is made is kept a secret, but it is non-inflammable, and in appearance resembles hard rubber, for which it is used as a substitute on account of its price, which is very much less.

Section "c" requires a mechanical separation of conductors from pipes or metallic material. While an inch of air is almost infinitely better insulation than the same thickness of any other material still it is impossible to be certain of *maintaining* an air gap between a wire and a neighboring pipe, as both pipes and wire are liable to sag or to get displaced. The safest kind of construction is, therefore, to use a solid and rigidly fixed separator, so that we may be sure of preventing any metallic contact with our conductor. This regulation is in line with the best practice concerning insulation for moderate pressures, which is to insist not so much upon a ridiculously high insulation on new work as upon a kind of construction which will permanently maintain an insulation which is high enough to insure *safety*.

The extreme care required by section "d" is necessitated, first, by the fact that devices attached to low potential circuits are handled by every one, and any contact of a low potential wire with one of high potential may bring the low potential circuit, or any device connected to it, up to the potential of the high potential circuit. In this way an ordinarily harmless contact may prove fatal to human life. Secondly, the devices used to protect a low pressure system are not suitable to protect it when subjected to an abnormally high pressure. Thirdly, the insulation which may be all right for a low potential system, may be strained and broken down by the high pressure, and when once the insulation has given way, the lower pressure keeps up the trouble which the higher pressure has started. The perfect insulation of wires of low potential from those of high potential is therefore even more important than the insulation of high potential wires from one another or from the ground.

Section "e" requires that in wet places there shall be not only a solid separator, but also an air separation. While almost any mechanical separation may do fairly well between wires and gas pipes, we must guard against using a material which will absorb moisture whenever we have a water pipe near our wire. A piece of tubing strung upon the wire or a split tube placed around the pipe and held in place by adhesive tape, or some such simple device, easily gives the desired construction and with but little labor or expense.

The first part of section "f" may be described as a precaution against poor workmanship. It requires that the wires must be joined mechanically to guard against poor soldering, and that they shall be soldered to guard against poor splicing. The solder is also necessary even if the joint is mechanically perfect, as even a good twist joint will in time deteriorate. The wire will oxydize, and the resistance of the joint will increase. This cannot be allowed, as any resistance in a circuit causes energy to be transformed into heat. The soldering of the joint, if properly done, insures a good, *permanent* joint. The definition under section "f" has already been referred to in the paper on high potential circuits.

The code neglects to give a definition of how to cover a joint with an insulation "*equal to that of the conductors.*" We know of no way in which this can be done by a wireman, but the rule is useful, for it certainly indicates that the insulation of joints must be as good as can be made, and it directs our attention to the fact that joints should be *avoided* as far as is possible. The best rule to observe in doing work is to avoid if possible the use of *any* joints in wires except where the joints come in the air between supports. The observance of this rule will call for the use of but little more wire than would be used if frequent joints were allowed. When we consider the time required to make a really first-class joint in insulation, and the time lost in making over joints which show up defective on being tested, we will see that this kind of construction saves considerable labor. It is safe to say that doing wiring without joints saves as much in labor as is lost in material, and this is the only way that we can be *certain* of securing good insulation.

CHAPTER IX.

CLASS C, LOW POTENTIAL SYSTEMS. PART III.

TEXT OF CODE COVERED BY THIS CHAPTER. SPECIAL RULES. 19. WIRING NOT ENCASED IN MOULDING OR APPROVED CONDUIT:— *a.* Must be supported wholly on non-combustible insulators, constructed so as to prevent the insulating coverings of the wire from coming in contact with other substances than the insulating supports. *b.* Must be so arranged that wires of opposite polarity, with a difference of potential of 150 volts or less, will be kept apart at least two and one-half inches. *c.* Must have the above distance increased proportionately where a higher voltage is used. *d.* Must not be laid in plaster, cement or similar finish. *e.* Must never be fastened with staples.

IN UNFINISHED LOFTS, BETWEEN FLOORS AND CEILINGS, IN PARTITIONS AND OTHER CONCEALED PLACES:—*f.* Must have at least one inch clear air space surrounding them. *g.* Must be at least ten inches apart when possible, and should be run singly on separate timbers or studding. *h.* Wires run as above immediately under roofs, in proximity to water-tanks or pipes, will be considered as exposed to moisture. *i.* When from the nature of the case it is impossible to place concealed wire on non-combustible insulating supports of glass or porcelain, the wires may be fished on the loop system, if encased throughout in *approved* continuous flexible tubing or conduit. *j.* Wires must not be fished for any great distance, and only in places where the inspector can satisfy himself that the above rules have been complied with, *k.* Twin wires must never be employed in this class of concealed work.

Before considering "*special rules*" for wiring, we will first consider *all* the ways in which it has been customary to run wires, and then what methods are allowed and what methods are recommended by the code. Wires are in general run in two ways: First, in accessible places, as upon the walls and ceilings of rooms; second, in inaccessible places, as in walls, and in the hollow spaces in partitions and between floors and ceilings. It has in the past been customary to run wires in all of the following ways: *In accessible places:* (1) The wires were fastened directly upon the walls and ceilings, usually by means of wooden cleats, but sometimes by iron staples. (2) The wires were attached to knobs of porcelain or glass or to cleats of porcelain which were attached to the walls or ceilings, and were so designed as to support the wires in the air, free from the wood work or anything but the insulating supports. These two methods of construction are known as "*open wiring.*" (3) The wires were placed in grooves in wooden moulding which was attached to the ceilings or walls. (4) The wires were drawn into tubes or "conduits," the conduits being attached to the walls and ceilings by means of staples or cleats. *In inaccessible places:* (1) Wires attached directly to walls and ceilings and concealed by being covered with plaster or cement. (2) Wires run in hollow spaces, as in partitions and between floors and ceilings. Both of these methods were known as "concealed wiring." When wires were concealed by running them in hollow spaces they were run in the following ways: (1) They were "*fished,*" *i. e.*, they were drawn into the space through one hole and drawn out of the space through another. (2) They were run directly upon the wood work (where wooden construction was used), the wires being held in place by cleats or staples or by being drawn through holes bored in timbers or joists. (3) The wires were occasionally placed in moulding, the wires and moulding being both concealed. (4) The wires were run upon glass or porcelain knobs or porcelain cleats, in the same manner as when run in accessible places, the wires being surrounded by porcelain bushings where they pass through timbers, joists, etc. (5) The wires were drawn into tubes or conduits, the conduits being put in place while the building was under process of construction, and the wires being subsequently drawn into them. We have spoken of the various ways in which wires *have been* run, as some of these methods, though quite popular in the past (on account of the ease and cheapness with which they could be applied), are now absolutely prohibited by the code.

Let us see how the code treats of the various methods of construction above enumerated. *In accessible places:* The cleating or stapling of wires upon walls or ceilings is forbidden by section "a" of Rule 19. The running of wires upon glass or porcelain knobs or porcelain cleats with porcelain or glass bushings where the wires pass through floors and partitions is approved by sections "a," "b" and "c" of Rule 19. In fact, these sections absolutely *compel* the use of this class of construction except when wires are enclosed in moulding or conduits. The method of running wires in moulding and conduit are considered at length in a later portion of the code. These methods are approved by the code. We will. devote a future chapter or chapters to the discussion of these systems. *In inaccessible places:* The concealing of wires by laying them in plaster or cement is specifically forbidden by section "d" of Rule 19. The reason for this requirement is that wires laid in plaster or cement are exposed to chemical actions which often destroy the waterproofing qualities of their insulating coverings. Partially slacked lime in plaster will "burn" the braid and rubber coverings of wires, and many kinds of plasters and cements, and even the tiles of which ceilings and partitions are constructed, contain chemicals which (either alone or in combination with moisture) will injure and sometimes completely destroy insulation. Again, it is almost impossible to repair defects in insulation laid in plaster. It is practically impossible to get a workman to make a joint in insulation that is water-tight so that it will not leak when placed in wet plaster. The consequence is that when we get a defect in the insulation of a wire laid in plaster, the only way to be sure of removing it is to remove the entire wire and replace it with another. This class of construction was for several years used almost exclusively in wiring fire-proof buildings, but the results obtained have been most unsatisfactory.

The method of "fishing" wires into hollow spaces was introduced into the art in the earliest days. The first plants installed were for the most part in old (*i. e.*, in finished) buildings, where hollow spaces were inaccessible. The only way then known to conceal wire in such buildings was to fish it into hollow spaces. It was fishing in a very literal sense. To get a wire from one point to another, the wireman would bore a hole in the wall or cut a small hole in the floor and then push a wire into the hole; then either he or another man would go to another hole, where it was desired to have the wire come out of the wall or floor, and, taking a piece of wire with the end bent up into a hook, he would fish until he had captured the loose end of the wire. Then he would drag the wire out of its hole and connect the end to his socket or switch, or perhaps start in again and fish to another hole. With this kind of work it was of course utterly impossible to know the condition or position of wire *between* the outlets. Wires might lie against pipes or be crossed and tangled up with one another without anyone being the wiser. Defective joints could not be discovered, and, in fact, no defective workmanship or material was likely to be discovered until it made trouble. It was so easy to rush in work of this kind and still have it pass inspection, when first installed, that many a man who wanted to skin the cost of a piece of work would even run a wire of inferior insulation inside a wall and tap on some ends of good rubber-covered wire to stick through the wall. This kind of construction has at last been condemned by the underwriters, and section "f" of Rule 19 demands a grade of work which cannot be obtained by "fishing."

The method of running wires *upon wood-work*, attaching them with cleats or staples and running them through holes in the wood, is also prohibited by section "f" and by section "a." This kind of work, once so popular, is now prohibited in accessible places, and it goes without saying that its use in *concealed* work should never be considered.

The use of moulding in concealed work is prohibited by the code in the portion devoted especially to mouldings.

The method of running wire in hollow spaces upon glass or porcelain knobs or porcelain cleats, with glass or porcelain tubes surrounding the wires where they pass through timbers, is approved by the code. This class of construction *must* be used to fulfill the requirements of sections "f," "g" and "h" of Rule 19. If the wire is *not disturbed* after it has once been installed, this kind of construction will, if properly done, secure almost absolute safety. This is the same grade of work that we have found to be satisfactory for *high potential* circuits. The wire in this manner would have an insulation good enough to secure safety even if it did not have a rubber covering. In fact if we could be assured that the wire run in this manner would *never be molested* after it had once been properly installed, we could use a *bare* wire without necessarily creating a hazard. Of course the use of good construction is no excuse for the use of inferior material.

The best practice is to use a high grade of insulated wire and to install it if possible in such a way that it would not create a hazard even if its insulation were injured or destroyed.

The last method mentioned, *i. e.*, the running of wires in conduit, is approved by the code. Considerable space is given, in another part of the code, to the manner in which the conduit should be installed and we propose to devote one or more chapters to the subject of conduits when we come to that part of the code. In summing up what we have stated above concerning methods of wiring and the code, we find that the following methods are approved by the code and that they are the *only methods allowed:* (1) Wires run on glass or porcelain knobs or cleats, (with bushings of same materials) either for "open" or "concealed" work. (2) Wires run in a suitable wooden moulding, (but not concealed work). (3) Wires run in a suitable conduit for either open or concealed work.

Sections "i," "j" and "k" of Rule 19 permit the use of a special kind of construction, in cases where it is practically impossible to install the work in the manner which is considered the best. This exception is made to provide a method by which the wires can be run concealed in *finished buildings.* The code requires that conduits for interior conductors shall be of material which is "not subject to mechanical injury by saws, chisels or nails," but as there is no *flexible* conduit on the market which fills this specification, a conduit is allowed, for this particular class of work, which is not tool proof. This kind of construction is infinitely better than the old practice of fishing the wires, and it is not liable to create a hazard, as there is comparatively little danger of mechanical injury to a conduit in a finished building, particularly in cases where it is not allowable to cut up the building enough to insert a standard conduit.

CHAPTER X.

CLASS C., LOW POTENTIAL SYSTEMS. PART IV.

TEXT OF CODE COVERED BY THIS CHAPTER. 20. MOULDINGS:—*a*. Must never be used in concealed work or in damp places. *b*. Must have at least two coats of water-proof paint or be impregnated with a moisture repellant. *c*. Must be made of two pieces, a backing and capping, so constructed as to thoroughly incase the wire and maintain a distance of one-half inch between conductors of opposite polarity and afford suitable protection from abrasion.

21. SPECIAL WIRING:—In breweries, packing-houses, stables, dye-houses, paper and pulp mills, or other buildings specially liable to moisture or acid, or other fumes liable to injure the wires or insulation, except where used for pendants, conductors: *a*. Must be separated at least six inches. *b*. Must be provided with an *approved* water-proof covering. (See Definitions.) *c*. Must be carefully put up. *d*. Must be supported by glass or porcelain insulators. No switches or fusible cut-outs will be allowed where exposed to inflammable gases or dust, or to flyings of combustible material. *e*. Must be protected when passing through floors, walls, partitions, timbers, etc., by water-proof, non-combustible, insulating tubes, such as glass or porcelain.

DEFINITIONS. RULE 21. SPECIAL WIRING:—Section *b*. The insulating covering of the wire to be *approved* under this section must be solid, at least $\frac{3}{64}$ of an inch in thickness and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water with a current of 550 volts after three minutes' electrification, and must *also* withstand a satisfactory test against such chemical compounds or mixtures as it will be liable to be subjected to in the risk under consideration.

Moulding.—Section "a," Rule 20, limits the use of moulding to dry places and even in dry places it is only allowed as a substitute for insulator or cleat work. We have seen that the first thing to be sought is accessibility. Nothing could be more inaccessible than a wire in a moulding inside a partition or between floors and ceiling. Again we have seen that moisture is the greatest foe to insulation. It is not therefore permissible to place wires in damp places as near together as they are placed in mouldings. In fact, in a damp place, wires in moulding are more exposed to moisture than wires placed near to one another in the air, as the wood of the moulding will absorb moisture and the wires will quickly become wet but will dry very slowly. Section "b" of the same rule is made necessary by the well known tendency of wood to absorb moisture even in a place which is not supposed to be wet. In the wiring of a building the moulding is placed against wet plaster or cement and unless some precaution is taken to prevent the wood from absorbing moisture the moulding will become saturated and will remain wet after almost everything else in the building has become dry. The surface of the wood which comes in contact with the plastered wall should always be painted or filled; and naturally the more thoroughly the moulding is made waterproof the better. Section "c" is inserted in Rule 20 to prevent the practice (almost universal in the past) of placing the wires against a wall and covering them with a grooved moulding. This method was, of course, cheaper than to provide wood to cover the wire and also to keep it away from the wall. The trouble with such construction was that the wire was placed in contact with the plaster while it was new and wet and that the rubber compound with which the wires were covered was liable to be injured by the action of any chemicals that might enter into the composition of the plaster. The moulding which is required by the code, must be so made that it separates the wires half an inch from each other and also covers the wires so as to keep them in place and at the same time protect them from any ordinary mechanical injury

The only practical form of moulding which will do these things is a moulding made of two pieces. There are many forms of mouldings, but in general the piece next to the wall is called the backing and the piece which covers the wires is called the capping.

We have spoken of moisture as being the greatest foe of insulation, yet pure water is not such a very good conductor. In fact it is a very poor conductor of electricity; but water which holds in solution any foreign matter either an acid or a salt is a pretty good conductor. As many chemical substances act directly to destroy the rubber compound which covers our wire, the conditions described in Rule 21 act unfavorably in two ways; first, there is a tendency to destroy the insulation, and second, the chemicals tend to furnish a good path for a leak after the insulating material has been injured or destroyed. By "pendants" are meant the wires which hang down and from which the lamp sockets are directly suspended. These wires cannot well be kept apart, but they should have an insulation as good as that of any other parts of the wiring. Section "a" of Rule 21 requires that the wires shall be kept six inches apart in places where they are exposed to the action of chemicals. This is equivalent to a decision that it is as difficult to maintain insulation on a low potential system, where the wires are thus exposed, as it is to maintain insulation on a high potential system, under ordinary conditions. In reality the difficulty is greater; and in some cases it is almost impossible to maintain a high insulation with any kind of material and construction.

Section "b" calls for the highest grade of insulated wire. The life of the insulation on a wire when exposed to chemical action is usually short. The best insulation that the market affords is none too good for this class of work and the safe thing to do (and the *cheapest* thing in the long run) is to buy the very best wire that can be bought for use in places such as are described in this rule. Even if we do this we cannot be sure of our results unless we select a make of wire which has a record for withstanding the action of the particular chemicals to which it is liable to be exposed.

The simple rule laid down in section "c" is the most important of any to be observed. Where wires are run in the air and are supported upon insulators, the only places where the current can leak from one wire to another or from a wire to the ground is *at the points of support*. If a wire is carelessly put up, it is liable to be injured at these very points. If the insulation becomes broken, then no matter how good it was originally, our wire is no better than a *bare* wire. If a short kink is made in a wire or if is tied too tightly to an insulator, a permanent strain is placed upon the rubber insulation and its life may be reduced to a small fraction of what it would be if put up with judgment and care. Only skill and care can secure work that will give good insulation and will insure safety in case the insulated covering of the wire is injured.

The kind of construction called for in section "d" is required by the code in dry places and it is still more imperative that it shall be employed in wet ones. In dry places the principal virtue of our glass and porcelain is that they are fire proof. In damp places however and especially in places where wires are exposed to chemical action we need glass or porcelain to help us maintain insulation.

In this connection, we should notice that most of the porcelain made in this country in the past and much of the porcelain now on the market, is almost worthless as far as insulation is concerned. Only a few years ago we were compelled to use glass exclusively for use in packing-houses and the like, owing to the inferior quality of the porcelain which was then used for making insulators. Inferior porcelain is so porous that it will absorb moisture like a sponge, so that all the insulation it affords is that of the thin glaze on the surface. Since knobs are not glazed on the bottom, a porous knob on a wet wall will become thoroughly saturated with moisture, and if there is a check in the glaze, the knob practically ceases to be an insulator at all. When porcelain is used for this work it should be thoroughly vitrified, and any porcelain which is not thoroughly vitrified should be condemned. We have seen that when a circuit carrying a current is opened, an arc is formed. This is just what we get when a circuit is opened by the opening of a switch or the blowing of a fuse. The danger of allowing a spark to be made in the presence of inflammable gases or of fine dust is too well understood by all insurance men to need any comment. By making an installation in accordance with the spirit of Rule 21 we can not only furnish light in places such as are described in section "d" (without creating a hazard), but a light which is safer than any other kind of illuminant.

The code requires that all wires, whether of high or low potential systems, shall be protected wherever they pass through walls by insulating tubes. For high potential systems and for the class of work referred to in Rule 21, the tubes must be of glass or porcelain or some other *incombustible* material. Rule 18, which we have considered in a previous chapter, allows the use of tubes of other materials on low potential systems, in places where wires are not liable to be exposed to moisture; but as almost any wall or partition is liable to be a place where wires are exposed to moisture, and, as tubes of porcelain are at present quite inexpensive, and nearly or quite as cheap as the other bushings referred to in Rule 18 and the definitions explaining that rule, it can hardly be considered good practice to run wires of any kind through walls or partitions without protecting them in the manner described in section "c" of Rule 21.

CHAPTER XI.

CLASS C, LOW POTENTIAL SYSTEMS. PART V.

TEXT OF THE CODE COVERED BY THIS CHAPTER. 22. INTERIOR CONDUITS*:—(See Definitions.) *a.* Must be continuous from one junction box or another, or to fixtures, and must be of material that will resist the fusion of the wire or wires they contain without igniting the conduit. *b.* Must not be of such material or construction that the insulation of the conductors will ultimately be injured or destroyed by the elements of the composition. *c.* Must be first installed as a complete conduit system, without conductors, strings, or anything for the purpose of drawing in the conductors, and the conductors then to be pushed or fished in. The conductors must not be placed in position until all mechanical work on the building has been, as far as possible, completed. *d.* Must not be so placed as to be subject to mechanical injury by saws, chisels or nails. *e.* Must not be supplied with a twin conductor, or two separate conductors, in a single tube. (See † Rule 22.) *f. Must have all ends closed* with good adhesive material, either at junction boxes or elsewhere, whether such ends are concealed or exposed. Joints must be made airtight and moisture-proof. *g.* Conduits must extend at least one inch beyond the finished surface of walls or ceilings until the

*The object of a tube or conduit is to facilitate the insertion or extraction of the conductors, to protect them from mechanical injury, and, as far as possible from moisture. Tubes or conduits are to be considered merely as raceways, and are not to be relied on for insulation between wire and wire, or between the wire and the ground.

† NOTE.—The use of two *Standard* wires, either separate or twin conductor, in a straight conduit installation is approved in the *iron-armored* conduit of the Interior Conduit and Installation Company, but not in any of the other approved conduits. (See Rule 22, *e.*)

mortar or other similar material be entirely dry, when the projection may be reduced to half an inch.

DEFINITIONS. RULE 22. INTERIOR CONDUITS:—The *brass-sheathed* and the *iron-armored* tubes made by the Interior Conduit and Insulation Company, the American Circular Loom Co. tube and the Vulca tube are approved for the class of work called for in this rule.

Interior Conduits.—We have already called special attention to the fact that in order to have the *best* kind of an installation, it is necessary to have the wires at all times *accessible.* Accessibility may be obtained in three ways: First, by running wires upon knobs or cleats, the wires being either in sight upon walls or ceilings, or in the hollow spaces, as in attics, unfinished rooms, ventilating shafts, etc., or in runways specially provided for the purpose. Second, by running the wires in wooden mouldings so constructed that we can remove the covering or "capping" and inspect the wires or remove and replace them in case of injury to the insulation. These two methods suffice to secure good insulation, but they do not, except in special cases, admit of construction which will allow the wires to be *concealed from view* and at the same time *protected against mechanical injury.* The third method consists of running the wires in a pipe or conduit so constructed that the wires can be readily withdrawn and other wires drawn in, if at any time the insulating covering of the wires is injured. This system, if properly installed, allows us to withdraw the wires for inspection and to readily insert them again. The object of the interior conduit is briefly and very clearly set forth in the note given above in the text of the code.

An interior conduit can often be used to good advantage in the place of moulding, but its *chief* use is to allow wires to be "*concealed*" *without being* "*fished*." To accomplish this result a conduit should fulfill two requirements: First, it should prevent the igniting of woodwork, in the event of the wires becoming overheated by excess of current, or in case an arc is set up either by a break in a wire carrying a current or by wires of opposite polarity becoming "crossed," *i. e.*, coming into electrical contact with one another either directly or through some conducting path. Second, it should furnish mechanical protection to the wires, so that the insulating covering of the wires will not be mechanically injured or destroyed.

The interior conduit, like everything else in the art, has passed through a period of evolution. Although the conduit system is still susceptible of improvement, it is to-day so well developed that we can apply it successfully and at a reasonable cost to almost all classes of concealed work. In considering the advantages and requirements of a conduit, we must consider the class of construction which it was designed to replace. It is necessary in most inside wiring for incandescent lamps to have our wires out of sight, or, as we commonly express it, "concealed." Before we had the conduit, this was accomplished in three ways: First, the wires were run on insulators or cleats upon beams and rafters, in the hollow spaces in walls, partitions, and below floors. Second, they were fastened with staples or cleats directly upon ceilings or walls and covered with plaster. Third, they were fished into the hollow spaces in partitions or between ceilings or floors. Whichever of these methods was employed, the wires were *inaccessible;* they were liable to *mechanical injury* from tools in the hands of plasterers, carpenters, plumbers, gas fitters and the like. They were also liable to be injured by *chemical action,* especially when laid in cement or plaster. Where wire is laid in plaster, in modern city buildings, the life of the insulation is a matter of complete uncertainty. The evolution of the conduit has brought about a gradual improvement in materials, appliances and methods of installation; but the advance has been chiefly in the matter of educating people to use it. Although thoughtful engineers have long seen the advantages to be derived by running wires in protecting pipes, it seemed as if the additional expense would be so great that such a system could never be successfully introduced. The first conduit placed upon the market was called "The Interior Conduit." The tubing was formed of strips of paper wound spirally layer upon layer, the paper being saturated with a water-proof compound. The tubes were joined at the ends with thin brass couplings or sleeves, which were slid over the ends of both tubes and crimped so as to form a practically water-tight joint. In order to get the conduit into use, an attempt was made to depend upon the *conduit itself* for *insulation.* It was thought necessary to do this in order to make conduit construction cheap enough to be extensively used. The attempt was made to save enough in the cost of insulating covering of the wires to pay or nearly pay for the tubing. The result of this experiment was disastrous in the extreme.

At first each tube contained two wires, which were insulated only by a wrapping of cotton. The idea was that the wires would either be insulated by the conduit itself, or, if the insulation was impaired, the wires would come into metallic connection with one another, when the result would be simply that the protecting fuse would melt and protect the circuit. New wires would then be drawn into the conduit. The scheme worked exactly according to the calculations, but it worked so well that the wires were practically crossed *all the time*. The next step was to use two conductors of underwriters' wire, or wire covered with cotton braid saturated with white paint. This wire lasted but little better. Next, two weather-proof wires were used, *i. e.*, wires covered with cotton braids saturated with a water-proof compound (two wires were placed in a tube). This wire lasted a little better, but soon went the way of the others. Next, the attempt was made to get along with moisture-proof insulation on one of the two wires only. One conductor was covered with a covering of "rubber," and the second wire was wound spirally around the first, outside the rubber covering, and a weather-proof braid was placed around the outside. This wire lasted fairly well where the conditions were favorable, but was not satisfactory for general use. The next step was to use a similar double conductor, with a second rubber covering around the outside conductor, so that the wires were insulated from one another and from the conduit with moisture-proof insulation. Having at last reached the point where the cost was practically the same as that of two rubber-covered wires, the next step was to use two wires with the same insulation that had been used for other concealed work, excepting that the insulation was not quite as thick as was used for wires laid in plaster. Having reached the point where the advantages of a conduit system had been demonstrated, and having learned by experience that good conduit construction *must be more expensive* than running wires fished or in plaster, the conduit manufacturers undertook to sell conduit on its *merits*, and took the stand that the extra expense of installation was justified on the score of safety, and that in the long run the owner would save in maintenance more than he lost in the first cost. Introduced along these lines, the interior conduit has become a success, and to-day it is extensively used on almost every installation where a high grade of insulation is desired, and its use is rapidly increasing. After the paper tube, another form of conduit, called "*vulca duct*," was brought out. The advantage claimed for this conduit is that it is absolutely non-combustible. The manufacturers of vulca duct early recommended the use of a separate tube for each wire, even where small wires, carrying the current of a few lights, were used. The next step was to place a mechanical protection in the form of a metal covering around the conduit. At first this was a covering of thin sheet brass, but finally it took the form of a substantial iron pipe. At last we have a conduit system consisting of what is practically a gas pipe with an insulating lining, the wire used being as good as is used for any class of construction. The covering of the wire provides the insulation, the tube provides the required accessibility, and where there is exposure to mechanical injury, the metal covering is used to furnish mechanical protection.

Section "a" Rule 22 means that the conduit must be continuous between outlets, and continuous in the sense of being as nearly as possible equivalent to a continuous water and air-tight tube, in accordance with section "f."

Section "c" is an imperative rule. Only by installing conduit and wire in this manner can we be assured that the wires will be *accessible*. The insertion of wires *after the conduit is complete in place* is the best test of the manner in which the conduit has been installed and it is the only way in which a concealed conduit can be tested after it is once installed and hidden from view.

Consideration of section "d" determines the kind of conduit best suited to any particular piece of work. The spirit of this rule requires that, in most cases where tubes are run in unfinished buildings, wherever tubes are run below floors and in general in all places where the conduit is liable to mechanical injury it should be "armored," *i. e.*, there should be a metal covering to protect the wire and it should be thick enough to turn a nail. The best conduit yet devised for mechanical protection is an ordinary gas pipe. The "iron armored" conduit of the Interior Conduit Company, is a gas pipe lined with a tube of paper saturated with a water-proof compound. The essential parts of a conduit are: first, a hole into which to draw the wire; second, the protecting covering for the wire. The *insulating lining* should *not* be depended upon for *insulation*, but its presence is approved by the underwriters, as providing an additional safe-guard.

Section "e" prohibits the use of two wires of opposite polarity in a single tube. This is a wise precaution in the case of wires carrying large currents for the reason that a "short circuit" (or crossing of the wires) might destroy the conduit or do enough damage to prevent the withdrawal and renewal of wires, before it would melt a large fuse-wire. The note under the definition to Rule 22 allows two wires of opposite polarity to be run in one tube; but where large wires are used it is no hardship to use a tube for each wire, and in general two tubes should be used (even if they are armored) except in tap circuits, *i. e.*, circuits running direct to lamp or fixture outlets and carrying a small current. In these "tap circuits" or as they are often termed "branch circuits," it is often necessary to run two wires in one tube in order to do a neat and mechanical piece of work.

Section "f" seems to call for a needless refinement; but the more nearly air and water-tight a conduit is made the better. The chief trouble in conduits has been due to condensation of moisture, which would collect in a pipe which sagged or was so bent that a portion of the pipe was lower than the outlets on both sides of it. The greatest care should be exercised in installing a conduit, but when it is once properly installed the results are most satisfactory. The cost of a conduit system is not as great as is generally supposed, and we are justified in demanding its use in all cases where it gives greater safety. In many cases it is cheaper to install iron armored conduit than to apply any other method that will secure equal safety and reliability; and even where the use of conduit materially increases the first cost, of concealed work, it is usually much cheaper in the long run owing to the saving in maintenance.

CHAPTER XII.

CLASS C., LOW POTENTIAL SYSTEMS. PART VI.

TEXT OF THE CODE COVERED BY THIS CHAPTER. 23. DOUBLE POLE SAFETY CUT-OUTS:—*a*. Must be in plain sight or enclosed in an *approved* box, readily accessible. (See Definitions). *b*. Must be placed at every point where a change is made in the size of the wire (unless the cut-out in the larger wire will protect the smaller). *c*. Must be supported on bases of non-combustible, insulating, moisture-proof material. *d*. Must be supplied with a plug (or other device for enclosing the fusible strip or wire) made of non-combustible and moisture-proof material, and so constructed that an arc cannot be maintained across its terminals by the fusing of the metal. *e*. Must be so placed that on any combination fixture no group of lamps requiring a current of six amperes or more shall be ultimately dependent upon one cut-out. Special permission may be given *in writing* by the inspector for departure from this rule in case of large chandeliers. *f*. All cut-out blocks must be stamped with their *maximum* safe-carrying capacity in amperes.

DEFINITIONS. RULE 23. DOUBLE POLE SAFETY CUT-OUTS:—Section *a*. To be *approved*, boxes must be constructed, and cut-outs arranged, whether in a box or not, so as to obviate any danger of the melted fuse metal coming in contact with any substance which might be ignited thereby.

We have already seen that a wire, or in general any conductor, is heated by the passage of a current through it. For a given wire, the greater the current the greater the temperature; and for a given current, the thinner the wire the greater the temperature. The size of wires must therefore be proportioned to the current they are intended to carry. In practice low potential circuits are always multiple arc circuits, so that the current in a circuit, such as we are considering, is proportional to the number of burning lights attached to the circuit, or if motors are attached to the circuit, the current is also proportional to the work which is being done by the motors. Even if the wires are of proper size to carry a current to supply all the lights and motors which are attached to a circuit, still we are liable to have current leaking across from one wire to another of our circuit, if the insulation becomes poor; and we may have an immense current rushing from one wire of the circuit to another, in case the wires come into metallic contact, thus forming what we call a "*short circuit.*" These conditions may at any time be brought about by poor construction or material, imperfect devices or by some unforeseen accident. It is the function of a cut-out to protect a circuit, if, from a defect or accident, the current becomes sufficiently great to *unduly heat* the conductors of the circuit or the conductors forming a part of any device attached to the circuit, as for example the wires upon an electric motor. By unduly heated we do not necessarily mean heated to a temperature that will *ignite inflammable material.* The wire must not become heated sufficiently to *injure the insulating qualities* of its covering. The cut-out protects the circuit by cutting it out, *i. e.*, by interrupting or as we say opening the circuit, thus disconnecting it electrically from the source of supply. As we have already seen a current flows only in a continuous or *closed* circuit, and if a gap is made in a circuit at any-point, thus destroying its continuity, the current instantly ceases to flow in that circuit. We have also seen that a current flows freely in a copper wire like water in a pipe, but that it will not flow through an insulating substance such as air. If we insert an air gap in a wire it stops the flow of electricity as effectually as we can stop the flow of water in a pipe by stopping it up with some solid material. The device which we use to stop the flow of electricity by making an air gap in a circuit is called a switch. A switch interrupts the flow of an electrical current in a wire in a manner analogous to that in which a valve interrupts the flow of a current of water or steam in a pipe. Our *cut-out* corresponds to an *automatic valve* which operates when the flow becomes excessive.

To appreciate these comparisons we must bear in mind that when we interrupt or open an electrical circuit, what we really do is to replace a portion of our conducting wire with a barrier of insulating air. To understand the uses and arrangement of cut-outs we must understand in a general way what a system of wiring is like. We have hitherto spoken of a circuit as if it consisted simply of two wires, one wire (the positive) carrying the current from our dynamo to the lamps or motors, and the other (the negative) conducting the current back to the dynamo. In practice the arrangement is not quite so simple. The large wire or cable leading from the dynamo is divided and subdivided, branches running off in various directions to motors or groups of lamps. This subdivision is carried on until we get to the slender wires which are attached directly to the sockets of the lamps. Every time that our positive wire branches off we have a corresponding branching of our negative wire, so that every branch consists of two wires, independent of one another but each connected back to its respective pole of the dynamo. The wiring of a building therefore consists of a *double network* of wires. Our conductors spread out and ramify like the branches of a tree. The main conductors from the dynamo correspond to the trunk. If we have circuits led off to each floor of a building these correspond to the main branches. If we subdivide these circuits and run smaller circuits to each room, these correspond to the smaller branches, etc. The smallest wires which connect to our lamp sockets correspond to the smallest twigs, and if we let the incandescent lamps be represented by the leaves of the tree our figure is complete, except that to represent our wiring completely we must imagine that (without breaking off any branches or twigs), we split our tree in halves, splitting trunk, branches, twigs and all, clear to the point where the leaves are attached. This analogy of a tree has always been present in the mind of the wireman, even if he did not stop to consider it. We speak of "trunk" lines, "branch" circuits, etc., and the names themselves suggest the arrangement without explanation. In the early days, wiring was laid out in a building without any special order or system. From the main wires branches were led off and from these branches were run smaller branches and so on, the wires decreasing in size with each division. This style of wiring was called the "*Tree System.*" The arrangement was as fortuitous as that of the branches of a tree and too frequently the quality of the lights was as varied as that of the fruit on a tree. To-day the wiring of a building is done on more scientific principles. The conductors divide branch and subdivide, but they are arranged in a more orderly and systematic manner. The changes of arrangement are interesting but it is not necessary to devote space here to a detailed description of them. The typical wiring system of to-day is laid out in much the same manner as a well designed system of gas piping, each pipe corresponding to a pair of wires.

We have used the word "circuit," sometimes to describe a pair of conductors with all their branches, and again to describe *one of the branches;* but we believe the connection in which the word is used will show which way it is applied in any particular case.

When we send a current of electricity however small through a wire, the wire becomes heated. If we increase the current sufficiently we can heat the wire red hot. A further increase will heat it white hot (an example of this is the loop in an incandescent lamp). We can carry this still further and by making our current large enough we can melt or *fuse* our wire. A fusible cut-out is simply a short piece of wire (usually of a material which fuses at a low temperature) inserted into one of the conductors of a circuit, and of such size that it will be fused by the passage of a current somewhat less than sufficient to unduly heat the conductor itself. In practice the piece of fusible wire is called a "*fuse.*" The device for containing the fuse and connecting it to the conductor is called a "cut-out block" or "fuse block." The name *cut-out* is used to include both the fuse block and fuse. Where a fuse is inserted into both the positive and negative sides of a circuit, both fuses being placed upon one fuse block, the device is called a "*double pole* cut-out." In early days circuits were protected only by *single* pole cut-outs, *i. e.*, by having a fuse inserted into *one* conductor of a circuit *only*. This practice has been abandoned, and the code allows only *double pole* cut-outs *in all cases*. The reason of this is that single pole cut-outs, while effective to prevent an individual circuit from an excess of current, will not necessarily prevent an excess of current flowing into a wire when, by any defect or accident, an electrical connection is made between the *positive* conductor of *one circuit* and the *negative* conductor of *another circuit*. Another point which should not be overlooked in this connection is that by using double pole cut-outs, we can at any time disconnect any circuit from the rest of the system by simply removing the fuses, thus enabling us to quickly and easily test the circuit. Section "a" of Rule 23 should be observed in order that cut-outs may be *easily inspected*. While a cut-out is a source of safety if properly designed and installed, it may become a *danger point* in case it is not constructed, installed and maintained in the manner required by the code. Convenience also dictates that cut-outs shall be so placed that they can be easily found and easily reached when it becomes necessary to make a test or to replace a fuse which has melted.

The parenthetical clause in section "b" shows us how to determine the size and location of cut-outs. Originally, the regulations of the underwriters required that cut-outs must be placed at every point where a change is made in the size of the wire. When this rule was made it was customary to do the wiring of the "tree system" almost exclusively. In this system the wires were reduced in size every time that they branched, the size of the wire in any branch being proportional to the number of lamps for which it carried current. The rule was a good one at the time it was made, as it practically required a cut out to be placed at every point where the wires branched, and such an arrangement was the only one that made it possible to cut up such a system of conductors so that one could test it out and locate faults. The method of wiring on the tree system with cut-outs wherever the size of wire changed gave safety, but it required a needless number of cut-outs, and the points where the wires branched were not always convenient or proper points at which to locate cut-outs. To-day we secure safety with a smaller number of cut-outs. The wiring is arranged so that the cut-outs are not distributed all over a building, but are bunched in convenient distributing centers, where they can be protected, and at the same time are easily accessible.

It is usually convenient to run but one circuit to a fixture, especially when the lights are to be controlled by a switch. The code, therefore, allows some discretion to the inspector in this kind of work. It is a pretty safe rule to allow not over about ten incandescent lamps, *i. e.*, five or six amperes on any lamp circuit. Exceptions may be made to this rule, but only when we are certain that the wires and devices are all suitable for carrying a greater current. We do not need to set such a low limit in order to protect our *circuits*, for we can always accomplish that by proportioning out the fuses to the size of the wires, but on a circuit carrying incandescent lamps it is best not to allow a current of more than about five or six amperes, as an arc formed by a greater current than this will demolish any ordinary socket.

Section "f" is a good rule, but it might be improved by stating that the capacity be marked on the *face* of the cut-out block so that an inspector can tell at a glance if it is all right. A current heats any *conductor* through which it flows, and a fuse block carries conductors in the form of metal connections to which the wires and fuses are attached. It is just as important to have these connections large enough as it is to have the wires of a proper size. The "maximum safe carrying capacity in amperes" of any conductor is the greatest current in amperes which it will carry continuously without becoming unduly heated. "Unduly heated" is a loose expression, and it does not mean any definite temperature, as the temperature which is allowable in any particular case depends upon a number of circumstances. Generally speaking, a bare metal conductor is considered unduly heated if it is so hot that one cannot with comfort hold it grasped firmly in the bare hand. With the ordinary hand, this means a temperature of about 150 to 175 degrees Fahrenheit. We will consider the question of carrying capacity more fully in our next chapter.

CHAPTER XIII.

CLASS C, LOW POTENTIAL SYSTEMS. PART VII.

TEXT OF THE CODE COVERED BY THIS CHAPTER. 24. SAFETY FUSES:—*a*. Must all be stamped or otherwise marked with the number of amperes they will carry indefinitely without melting. *b*. Must have fusible wires or strips (where the plug or equivalent device is not used), with contact surfaces or tips of harder metal, soldered or otherwise, having perfect electrical connections with the fusible part of the strip. *c*. Must all be so proportioned to the conductors they are intended to protect that they will melt before the maximum safe-carrying capacity of the wire is exceeded.

25. TABLE OF CAPACITY OF WIRES:—It must be clearly understood that the size of the fuse depends upon the size of the smallest conductor it protects, and not upon the amount of current to be used on the circuit. Below is a table showing the safe-carrying capacity of conductors of different sizes in Brown & Sharpe gauge, which must be followed in the placing of interior conductors :—

	TABLE A—CONCEALED WORK.	TABLE B—OPEN WORK.
B. & S. G.	*Amperes.*	*Amperes.*
0000	218	312
000	181	262
00	150	220
0	125	185
1	105	156
2	88	131
3	75	110
4	63	92

	TABLE A—CONCEALED WORK.	TABLE B—OPEN WORK.
B. & S. G.	*Amperes.*	*Amperes.*
5	53	77
6	45	65
8	33	46
10	25	32
12	17	23
14	12	16
16	6	8
18	3	5

NOTE.—By "open work" is meant construction which admits of all parts of the surface of the insulating covering of the wire being surrounded by *free* air. The carrying capacity of 16 and 18 wire is given, but no wire smaller than 14 is to be used except as allowed under Rules 18 (*a*) and 27 (*d*).

Before taking up the subject of fuses, let us consider more fully the requirements of Rule 23 (the text of which was printed in our last chapter) relating to cut-outs. Section "b" may be stated as follows: "Every wire shall be protected by a fuse of such a size that it will melt before the wire becomes unduly heated." Cut-out bases or "blocks" are made of marble, slate, glass or porcelain. For ordinary sizes porcelain is now universally used. It is the best material, as it is strong, is easily moulded into convenient forms, is cheap, and, when thoroughly vitrified, is a first-class insulator. When a fuse melts and a circuit carrying a current is opened, we of course have a flash, and the greater the current the greater the flash. Section "d" requires such a design of cut-out as shall prevent the blowing of a fuse from igniting any adjacent inflammable material. Safety is usually secured, first, by enclosing the cut-outs in a box or cabinet with a fire-proof lining; second, by having the cut-out so designed that each fuse is covered. This last is accomplished by providing the fuse block with a mica or porcelain cover, or by using a plug, as mentioned in section "d." The "plug" is a device which connects the fuse with the circuit in the same manner that an Edison lamp is attached to a circuit. The fuse plug is just like the base of an Edison incandescent lamp, except that a piece of fuse wire replaces the wires leading to the loop or filament, and that the base has a metal cover to prevent the melted metal from blowing out. These plug cut-outs are used for circuits carrying currents up to about 15 amperes; and for small currents they are both convenient and safe.

A "combination fixture," mentioned in section "c," is a chandelier or bracket, designed to carry both gas and electric lights. A circuit to a fixture ought to be protected by a small fuse if possible. From the nature of its construction, most combination fixtures have to carry small wires. Again, it would be disastrous to have an arc of many amperes formed in a combination fixture, as it might burn a hole in a gas pipe and ignite the gas.

We have seen that the branch blocks must be so proportioned that the conducting metal will carry the current without overheating, and that in order that we may be sure of having connections of proper size, the blocks must be marked with the maximum number of amperes that the cut-out is designed to carry. We now come to the subject of "*fuses.*" A fuse has been described as a piece of wire of such a size and material that it will melt before the current becomes sufficiently great to unduly overheat the conductors of our circuit. The fuse is usually of a material which is a poor conductor, and which will melt at a low temperature. It is not *essential*, however, that such a material be used. Any metal may be used if the wire is made of the proper size, but by using a poor conductor and a metal which fuses at a low temperature, a wire can be made which, though of a respectable size, will be fused by a small current. The question of the *best* material for fuses is still a mooted one, but experience has thus far led to the use of some such metal as above described. The most common material used is an alloy of lead, such as lead, antimony and tin.

We have already seen that the fuse must be of such a size as to melt before the current can overheat the smallest wire depending upon it for protection. As fuses differ in material, the *appearance* of a fuse is no indication of the number of amperes which it will carry without melting. All fuses ought, therefore, to be marked so that *anyone* can tell how many amperes it will take to melt it. Unless this rule is observed, circuits will seldom be properly fused, and, what is more, no inspector can tell whether or not they are properly fused.

Section "b," though often violated, is one which should always be observed. This rule prohibits the fastening of fuse wires into a cut-out block by fastening the ends of a soft wire under the head of a screw. The reason for this is that a soft metal like lead cannot be held firmly in place by clamping it. The metal will gradually but surely spread out under pressure until the wire becomes loose in its fastenings. Wherever we have a joint or contact there is resistance. The poorer the contact the greater the resistance, and consequently the more the joint will be heated by a given current. When, therefore, our joint becomes loose it begins to heat. Again, as soon as the joint becomes loose, the surface of the fuse is exposed to the air and it quickly oxidizes. This oxidation still further increases the resistance of the joint, and soon we find that the fuse will blow with a current much smaller than that for which it was designed. The blowing of the fuse in itself would do no special harm, but the chances are that it will be replaced by a larger fuse, so that wire will not be properly protected. Aside from the question of safety, it is poor engineering to install a safety device that will not, as nearly as possible, furnish the *same protection* at *all times*. Again, in the case of *small* fuse wires it is necessary to have some sort of tip to the wire in order to have a place on which to mark the capacity of the fuse. Section "c" is a rule which we have already considered under the subject of cut-outs. We have spoken of a *fuse* as a *wire* in the same way that we have spoken of our *conductors* as *wires*. As a matter of fact, our conductor, if very large, may consist of a bar of copper instead of a wire, and in the same way our fuse, if large, may be (and usually is) a flat strip of "fuse metal." Such fuses are called fuse strips. Whatever the form of our conductor or our fuse, the fuse must be proportioned to the size of the *smallest conductor* which it has to protect. A conductor is properly protected when there is *between it and the dynamo* a fuse which will be melted by a current which is smaller than the "*maximum safe carrying capacity*" of the conductor.

This brings us to the subject of *carrying capacity* of wires. The term "safe carrying capacity," or, as we more commonly say, "carrying capacity," of a wire is a term quite commonly misunderstood. It has, however a very definite meaning. The safe carrying capacity of a wire is the maximum current in amperes which it is allowed to carry by the underwriters. The safe carrying capacity for any ordinary size of wire is given in the code, in the table which is printed above. This table gives the maximum currents that the various sizes of wires will carry without unduly overheating. The values have been determined by calculation and experience. We have stated that a wire is unduly overheated when it becomes hot enough to injure the insulating material with which it is covered. Of course, one kind of insulation will stand a higher temperature without injury than another, and again, the temperature to which a given current will heat a certain sized wire will depend upon the original temperature of the wire and the opportunity which it has for cooling. We cannot, however, have a different table of carrying capacities for every kind of wire and construction, and the table given above is one which leaves a margin of safety in any ordinary construction. Upon examining the above table, the reader will find that apparently there is no direct relation between the size of a wire and the current which it is allowed to carry. It may be well, therefore, to take a little space to show why this is so; as such an explanation will show the importance and necessity of a table of maximum safe-carrying capacities.

We have seen that any conductor offers a resistance to the flow of a current of electricity in a manner analogous to that in which friction opposes the flow of water in a pipe. We have also seen that it is necessary to expend work to overcome resistance, and that this work represents a loss of energy, the same as when work is done to overcome friction. This lost energy, like the energy lost in overcoming friction, is transferred into heat, so that the electrical energy lost in a wire has the effect of raising the temperature of the wire. The calculation of the loss of energy in a wire carrying an electrical current is a much simpler matter than the calculation of the loss from friction in a water pipe. The loss per foot in a *given wire* is proportional to the *square of the current*, *i. e.*, the loss in power or the heat generated will be *four* times as great with a current of *two* amperes as with a current of *one* ampere. Again, with a *given current* the loss is inversely proportional to the *sectional area* or "cross section" of the wire; so that, if we have two wires, one one-half of an inch in diameter and another one-fourth of an inch in diameter, the sectional area of the first wire will be four times as great as that of the second, and if the two wires carry the same current, the loss in the larger wire will be only one-fourth of that in the thinner one. It would *seem* at first thought, therefore, that the larger wire could be allowed to carry *four* times the current of the smaller one without becoming any hotter. The problem is not, however, quite as simple as that. Let us take the example of the two wires, the first one-half inch and the second one-fourth inch in diameter.

Suppose that each wire carries a current of one ampere; then the loss in the larger wire will be but *one-fourth* that in the smaller wire, as the larger wire has *four* times the *area*, and therefore *one-fourth* the *resistance* of the smaller. If now we increase the current in the large wire to four amperes we shall increase the loss, or, what is the same thing, we shall increase the amount of heat generated *not four* but *sixteen* times, or in the ratio of the *square* of the currents. The result will be, therefore, that the heat generated will be *four times* that generated by one ampere in the small wire. As the larger wire has four times the mass of metal in the smaller one, it might still seem as if the temperature of the two wires would be the same; but the *temperature* of the wire is determined, not only by the amount of heat *generated*, but by the amount of heat which the wire *loses* in a given time. When the amount of heat generated in a given time is equal to that lost in the same time, the wire comes to a fixed temperature, and the faster the heat can be conducted or radiated from the surface of the wire the lower will be that temperature. (This is the reason that we have two tables of carrying capacity, one for wire suspended freely in the air and another where the wires are enclosed so that the heat does not get a chance to radiate into the cooler air.) The amount of heat *generated* in our larger wire is four times that generated in the smaller one, but the amount of heat lost by *radiation* is proportional to the *surface exposed*, and the larger wire has *not four*, but only *two times the exposed surface* of the wire of one-half the diameter. The result is that the *large* wire will get *hotter* with *four* amperes than the *small* wire will with *one* ampere. It follows, therefore, that if one wire has twice the sectional area of another, it will have something *less* than twice the safe-carrying capacity.

Upon consulting the table, we will see that while a No. 0 wire has almost exactly twice the area of a No. 3 wire, the No. 3 wire is allowed to carry 75 amperes, while the No. 0 wire is allowed to carry only 125 amperes. The greater the difference in the sizes, the more conspicuously is this shown in the table. While a No. 10 wire may carry 25 amperes, a No. 0 wire (with *ten* times the sectional area) is allowed to carry only *five* times that current. The calculation of the relative currents allowed for different sizes of wires involves considerable figuring, and a table of "capacities" is a most useful thing, and no wire used in electrical construction should ever be allowed to carry a greater current than that allowed in the table. The table of capacities shows what current a wire may carry with *safety*, but the wireman must not make the mistake of thinking that the table is any guide to the size of wire to be selected for any particular circuit. The wire *must not be smaller* than that given in the table, but in many cases the wire must be larger in order to give the proper pressure at the lamps. The *temperature* of a wire is determined by its size, the current which it carries and by its surroundings, *it is independent of the length.* The *total* amount of energy lost in a wire is proportional to its length, so that in calculating a wire from an *engineering* standpoint, the length of the circuit must be considered. The proper way to select the size of wire required for any particular case is to calculate the size which will give the maximum loss consistent with good service, and then consult the table of "capacities." If the calculated size is larger than that allowed by the code for the current to be carried, use it; if it is smaller than the size allowed by the code, then take the size allowed in the table.

The table of safe-carrying capacities does not apply to wires used in the construction of dynamos or motors nor to the wires used in rheostats. The rules which we have already considered demand that the installation of machines, rheostats, etc., shall be so made that they may become hot without causing a hazard.

CHAPTER XIV.

CLASS C., LOW POTENTIAL SYSTEMS. PART VIII.

TEXT OF THE CODE COVERED BY THIS CHAPTER. 26. SWITCHES:— *a*. Must be mounted on moisture-proof and non-combustible bases such as slate or porcelain. *b*. Must be double pole when the circuits which they control supply more than six 16-candle-power lamps or their equivalent. *c*. Must have a firm and secure contact; must make and break rapidly, and not stop when motion has once been imparted by the handle. *d*. Must have carrying capacity sufficient to prevent heating. *e*. Must be placed in dry, accessible places and be grouped as far as possible, being mounted, when practicable, upon slate or equally non-combustible back boards. Jackknife switches, whether provided with friction or spring stops, must be so placed that gravity will tend to open rather than close the switch.

FIXTURE WORK:—*a*. In all cases where conductors are concealed within or attached to gas fixtures, the latter must be insulated from the gas pipe system of the building by means of *approved* joints. The insulating material used in such joints must be of a substance not affected by gas, and that will not shrink or crack by variation in temperature. Insulating joints, with soft rubber in their construction, will not be approved. (See Definition.) *b*. Supply conductors and especially the splices to fixture wires, must be kept clear of the grounded part of gas pipes, and where shells are used the latter must be constructed in a manner affording sufficient area to allow this requirement. *c*. When fixtures are wired outside, the conductors must be so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture. *d*. All conductors for fixture work must have a water-proof insulation that is durable and not easily abraded, and must not in any case be smaller than No. 18 B. & S., No. 20 B. W. G., No. 2 E. S. G. *e*. All burrs or fins must be removed before the conductors are drawn into a fixture. *f*. The tendency to condensation within the pipes should be guarded against by sealing the upper end of the fixture. *g*. No combination fixture in which the conductors are concealed in a space less than one-fourth inch between the inside pipe and the outside casing will be approved. *h*. Each fixture must be treated for "contacts" between conductors and fixtures, for "short circuits" and for ground connections before the fixture is connected to its supply conductors. *i*. Ceiling blocks of fixtures should be made of insulating material; if not, the wires in passing through the plate must be surrounded with hard rubber tubing.

28. Arc Lights on Low Potential Circuits:—*a*. Must be supplied by branch conductors not smaller than No. 12 B. & S. gauge. *b*. Must be connected with main conductors only through double pole cut-outs.

Definition. Rule 27. Fixture Work:—Section *a*. Insulating joints to be *approved* must be entirely made of material that will resist the action of illuminating gases, and will not give way or soften under the heat of an ordinary gas flame. They shall be so arranged that a deposit of moisture will not destroy the insulating effect, and shall have an insulating resistance of 250,000 ohms between the gas pipe attachments, and be sufficiently strong to resist the strain they will be liable to in attachment.

In this chapter and the one which follows it, we will cover what remains of the code, upon the subject of low potential systems. This portion of the code deals with the details of electrical construction and electrical appliances. While the principles governing construction and design have been covered in the preceding chapters of the code, still there are certain mistakes which have been so repeatedly and persistently made year after year, that rules upon these particular points are necessary. In electrical, as in mechanical construction, "The strength of any structure is the strength of its weakest part." The points referred to in this part of the code are those which experience has shown to be weak points in our electrical structure. It will be noted that the rules at the head of this chapter, and those immediately following, state specifically that certain things *shall* and certain things *shall not* be done. It is impossible in our allotted space to describe the *details* of electrical construction or electrical appliances. To do this so as to give an intelligent idea of an electrical device, to one who has not seen the device, would require the use of illustrations or diagrams and would consume much space. We would suggest that those of our readers who are not familiar with the appearance of the appliances referred to in the code, take this occasion to inspect *the things themselves*, either at an electrical supply store or in some electric plant, as a knowledge of what the most common electrical devices look like cannot fail to be interesting and will aid one more than anything else to understand their uses and requirements. We make this suggestion, as the *names* of things electrical are often misleading; for example: a *switch* might be expected to be a device for *switching* a current from one path to another, while, as a matter of fact, a switch is the name used in the code for a device to *interrupt* or *open* a circuit.

Switches.—We have seen that a branch circuit, to a lamp or to a group of lamps or to a motor, consists of *two* wires, one a *positive* wire, by which the current is led from the positive wire of the main circuit *to* the lamp or motor, and the other or *negative* wire, by which the current *returns* to the negative wire of our main circuit. When a switch is so constructed as to open both of these wires at the same time, it is called a "*double pole switch.*" Such switches are required by the code for all circuits carrying more than six lights, that is to say for any circuit carrying a current of over *three amperes.* This is desirable for two reasons: First, it is necessary to have a double pole switch in order to completely disconnect a circuit from the rest of the system, so as to test it. Second, when we use a double pole switch, we make a break in *two places* at the *same time*, so that the arc, which is momentarily formed on the opening of a circuit carrying current, is *divided* and the danger of burning the switch is thereby greatly decreased. A "*firm contact*" is necessary as *every* contact offers a resistance to the flow of current, and the poorer the contact the greater the resistance. Good contact is maintained by good mechanical construction and by having a sufficiently large *surface* of contact. As an arc is formed on breaking a current, the quicker the break the better for the switch. In order that the break must be quick, the switch must be so designed that the moving part is thrown by a *spring* which, as soon as it acts on the switch, throws it wide open. It is also desirable to have a switch *close* quickly, and this too is accomplished by the use of a spring. When a switch is opened and closed by a spring, it is called a "*snap*" switch. This style of switch is what is referred to in section "c" Rule 26. *Snap* switches are required for all circuits, except circuits carrying large currents.

For large currents the switches are of the "jackknife type and are placed on a switchboard or in a cut-out cabinet. Section "d" refers to the thickness of conducting metal. A switch should not heat enough so that the heat can be noticed upon feeling of it with the bare hand. The material of which most switches are made is not more than half as good a conductor as copper, and sometimes it is a *very poor* conductor. The result is that most switches are too small for the currents which they are intended to carry. Heating is always a sure indication of poor material, insufficient surface or poor workmanship; or a combination of these defects. A "*jackknife*" switch is the name applied to the form of switch which is almost universally used where snap switches are not required. The form is suggested by the name, the switch being designed so that the blade or metal strip which closes the circuit, shuts into the contacts in the same manner that the blade of a jackknife switch shuts into the handle. These switches may be, but usually are not, equipped with springs to throw the blades. It will be readily seen that a switch of this kind placed vertically upon a wall will be so arranged that the blade, when open, will have a tendency to fall, and this will tend to *close* the switch, if the *contacts are below the blade.* If the arrangement is reversed the weight of the blade will tend to keep the switch *open.* Sometimes a spring is used to keep the switch handle straight out from the wall and sometimes the friction on the joint in which the blade turns is sufficient to hold the blade in any position in which it is placed, but since springs get weak and joints get loose, the best way is to install the switch so that when opened the blade will fall away from the contact. When thus installed the switch cannot become closed by any accident except the carelessness of an attendant, or the interference of some meddlesome person of an investigating turn of mind.

Fixtures.—Fixtures are always weak points in the insulation of electrical wiring in a building. As gas pipes are directly connected to the ground, any defective insulation of a circuit in a fixture immediately "*grounds*" our conductor. To secure insulation therefore we insulate our wire, insulate the conducting parts of our sockets from the fixture, and then, as an additional precaution, we insulate the *fixture itself* from the gas pipe. We speak now of what is called a "*combination fixture*," *i. e.*, a fixture carrying both gas and electric lights. In order to insulate the fixture itself and at the same time leave an opening for the gas to flow into the pipe of the fixture, we use what is known as an insulating joint. This joint is inserted into the gas pipe just below the ceiling. There are innumerable varieties of these insulating joints, some of them pretty good, but most of them pretty bad. They have been made with all kinds of insulation, hard rubber, soft rubber, glass, leather, and everything else that has ever been used as an insulator. The only rule to follow in selecting a joint is to use one that has been tested and approved by the underwriters. As we must insulate all fixtures from gas pipes, we must, of course, also insulate our conductors from the gas pipes, and must keep them away from them altogether. Where the gas pipe comes through a wall or ceiling we place an insulating joint, but *between* the *joint* and the *wall* or ceiling the pipe is *grounded*, we must therefore keep our wires away from *this part* of the pipe. The shell referred to in section "b" is the "*canopy*" which covers the hole where the pipe comes through the wall or ceiling. This canopy should be fastened to the fixture below the insulating joint, it should be free from the ceiling and should be large enough so that the joints in the wires inside can be kept well away from the uninsulated part of the pipe. It has in the past been quite a popular practice to transform old gas fixtures into combination fixtures by attaching sockets to them and running the wires to the sockets on the outside of the fixture. This kind of work was not ornamental at best, and the efforts made to prevent the appearance being very ugly resulted in pretty poor insulation. Section "c" refers to this class of work. To secure good insulation and a neat appearance with this kind of work is more trouble and expense than a combination fixture is worth. The practice is not now very common, but a fixture when wired this way should be wired for safety rather than beauty. Although in ordinary wiring no wire should be used smaller than No. 14 B. & S. or 16 B. W. G. gauge, it is sometimes necessary to use a smaller wire in a fixture carrying a few lights, as the space for wire in a fixture is often very limited. In using this fine wire, however, we should remember that the table of safe carrying capacities only allows a current of three amperes in a No. 18 B. & S. wire. Section "e" is to prevent the mechanical injury of the insulation of a wire, while it is being drawn into a fixture. Section "f" applies to an *electric* (not a combination) *fixture*, *i. e.*, a fixture carrying *only electric lights*. It is to protect the insulation from our old enemy *moisture*. Section "g" is for the mechanical protection of the insulation of a wire, in a combination fixture. In a combination fixture wires are run between the gas pipe and the surrounding ornamental shell, as it is the only place to run them and have them *concealed*. It is a wise rule, as the practice of fixture manufacturers has been to build a fixture so that nothing larger than *bell* wire could be hauled into it. All fixtures should be thoroughly tested in the shop where they are wired, and again after they are up in place and before the wires in the fixtures are connected to the wires in the building. This second test shows any injury to insulation that may have been caused in the installing of the fixture, and at the same time shows whether the insulating joint properly insulates the fixture itself. When combination fixtures are used they are attached to the gas pipes, but where simple electric fixtures are used they must be attached to some support provided for that purpose. If it were feasible it would be well to use an insulating and fire proof material for a support, but, in practice, the fixture is usually supported from a *wooden block*, which is fastened to the ceiling. When thus supported the wires should be treated as in cases where they pass through walls and ceilings, and be separated from any wood-work by insulating and non inflammable bushings. Porcelain tubes of convenient form and size are the best for this purpose

CHAPTER XV.

CLASS C, LOW POTENTIAL SYSTEMS. PART IX.

TEXT OF THE CODE COVERED BY THIS CHAPTER. 28. ARC LIGHTS ON LOW POTENTIAL CIRCUITS:—*a*. Must be supplied by branch conductors not smaller than 12 B. & S. gauge. *b*. Must be connected with main conductors only through double pole cut-outs. *c*. Must only be furnished with such resistances or regulators as are enclosed in non-combustible material, such resistances being treated as stoves. Incandescent lamps must not be used for resistance devices. *d*. Must be supplied with globes and protected as in the case of arc lights on high potential circuits.

29. ELECTRIC GAS LIGHTING:—Where electric gas lighting is to be used on the same fixture with the electric light: *a*. No part of the gas piping or fixture shall be in electrical connection with the gas lighting circuit. *b*. The wires used with the fixtures must have a non-inflammable insulation, or, where concealed between the pipe and the shell of the fixture, the insulation must be such as required for fixture wiring for the electric light. *c*. The whole installation must test free from "grounds." *d*. The two installations must test perfectly free from connection with each other.

30. SOCKETS:—*a*. No portion of the lamp socket exposed to contact with outside objects must be allowed to come into electrical contact with either of the conductors. *b*. In rooms where inflammable gases may exist, or where the atmosphere is damp, the incandescent lamp and socket should be enclosed in a vapor-tight globe.

31. FLEXIBLE CORD:—*a*. Must be made of conductors, each surrounded with a moisture-proof and non-inflammable layer, and further insulated from each other by a mechanical separator of

carbonized material. Each of these conductors must be composed of several strands. *b*. Must not sustain more than one light not exceeding 50 candle power. *c*. Must not be used except for pendants, wiring of fixtures and portable lamps or motors. *d*. Must not be used in show windows. *e*. Must be protected by insulating bushings where the cord enters the socket. The ends of the cord must be taped to prevent fraying of the covering. *f*. Must be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws. *g*. Must be equipped with keyless sockets as far as practicable, and be controlled by wall switches.

32. DECORATIVE SERIES LAMPS:—Incandescent lamps run in series circuits shall not be used for decorative purposes inside of buildings.

Although arc lamps are for the most part operated in *series*, and upon *high potential systems*, still there is no difficulty in operating them on *low potential* systems, as the ordinary arc lamp requires only a pressure of 45 to 50 volts. Thousands of lamps are so operated, and the practice is becoming daily more common. The only difference in the two methods of operation is that, when arc lamps are operated in *series* on high potential systems, a lamp is extinguished or cut out by *shunting the current*, *i. e.*, connecting together the two wires entering the lamp by a low resistance path; while on a *low* potential system the lamp is cut out or extinguished by *opening* the circuit to the lamp. An ordinary arc lamp takes a current of five, six or ten amperes, and, as seen by the table already given, the code allows a current of 12 amperes in a No. 14 wire (B. & S. gauge) when it is concealed and 16 amperes when it is exposed.

But an arc lamp takes a larger current than its normal amount when it is first started, and again it is customary to operate two lamps in series on most low potential circuits, so that the code requires the use of a No. 12 wire which is allowed to carry 17 amperes for concealed and 23 amperes for open work. As the two lamps which are in series are frequently located some distance apart, it is often *cheaper* to connect one wire of the lamp circuit to the main wiring at one point and the other wire at some distant point. This kind of construction leads to the scattering of cut-outs over a plant, and is prohibited by section "b" of Rule 28.

As arc lamps usually require pressure of about 50 volts each, and as most incandescent lamps, in isolated plants, are operated at 110 volts, it is apparent that when two arc lamps in series are attached to the same circuit as incandescent lamps, there is a surplus of about ten volts pressure. In order that the arc lamps shall not get too much pressure, this extra pressure is taken up by inserting into the circuit to the lamps some sort of a resistance, usually a coil of German silver wire. This resistance must be treated as any other resistance in a rheostat or resistance box, and must be considered as a source of heat and enclosed, so that it cannot create a hazard, no matter how hot it gets. The use of incandescent lamps is prohibited, as their use, as usually installed, is dangerous. In order to make a resistance to carry 5 or 10 amperes with incandescent lamps, it is necessary to use a number of lamps in multiple with one another, and when one of the lamps burns out, an excess of current is sent through the survivors, and every time a lamp gives out, a greater overload is thrown upon the remaining ones. As incandescent lamps are only used in order to make a *cheap* resistance, they are seldom so placed that the action referred to will not cause a hazard. As the action of an arc lamp is practically the same, no matter to what kind of a circuit it is attached, section "d" requires the same safeguards that we have already seen are necessary to insure safety in arc lighting.

Electric gas lighting concerns the underwriters and the engineer only as it may interfere with the safety of the electric lighting. Electric gas lighting devices are operated by a few cells of battery giving out a small current at a pressure of a few (usually about three) volts. Where electric gas lighters are used upon *combination fixtures*, or fixtures carrying both gas and electric lights, it is essential that great care shall be taken. We have seen that the fixture itself must be insulated from the ground by an insulating joint, and it is evident that it is not permissible to use any device that will destroy this insulation. The practice of using a ground return (*i. e.*, using the fixture as a part of the battery circuit) is not allowable on combination fixtures, and, as the battery wire may easily come into contact with the electric light wires, it is also necessary that they shall have the same grade of insulation, where both are run in the same fixture. These regulations are very important to secure safety, and they have been called forth by sad experience.

Section "a" of Rule 30 is essential to the safe *maintenance* of a plant. Although a socket may be attached to a flexible cord and suspended in the air, still there is always a chance that the socket will be allowed to hang or swing against a gas pipe or something equally well grounded. Nearly every machine shop in the country is a good example of this fact. Sockets should, therefore, be designed to give good insulation, and they should also be *well made*. This last point is not sufficiently considered, judging from the sockets most seen in the market. More attention should be paid to it; a good socket is now very cheap, and a poor socket is a bad investment from any point of view. Section "b" of the same rule is to prevent an explosion from being started by an accidental arc in a socket or lamp. The use of an electric spark for firing explosives is so familiar to every one that the importance of this regulation is self-evident.

Flexible cord is what is ordinarily called "*lamp cord*," it consists of two conductors twisted together, it is familiar to almost everyone. Usually it is covered with green cotton braid. It has been a weak point in most installations. Where the best of rubber-covered wires has been used for the wires on cleats or knobs it has been customary to use almost anything for insulation of lamp cord. The reason is that the cord is usually in the air where it cannot make a "ground;" but the fact that the cord is the best kind of a place to get a contact between two conductors, seems to have been often overlooked. Section "a" explains what kind of cord must be used. Section "b" limits the use of the cord to circuits for small currents of not over three amperes; as an arc, once started between the two wires of a cord, will (if of any strength) soo.. burn the cord in two, and allow the lamp and perhaps allow some burning braid to fall down upon the inflammable material which is usually at hand on such occasions. Section "c" is aimed at the practice once common, but now prohibited, of doing wiring with cord. It is very convenient to extend the wiring of an existing plant by running circuits to lamps here and there with cord, fastening the cord in place with staples. Miles of cord have thus been run, and no end of trouble has been the result. The insulation of all cord is low. Even if the insulating material is good, the covering is thin and will not stand dampness or mechanical strain. The use of cord for *temporary* work has been extensive. Unfortunately it seems as if the most permanent thing in electrical work is "*temporary construction.*" The same care must be taken to secure safety whether work is permanent or if intended to be temporary. The temptation to do temporary work with cord in *show windows* is so great that a special section is devoted to this offense. Show windows are usually filled with inflammable material, they have a faculty of condensing moisture, and a flexible cord in a show window is a very handy thing to fasten things to with pins. The use of cord in show windows is one of the things that renders the life of the electrical inspector unhappy; without section "d" it would probably be unendurable. Section "e" calls for bushings to protect the cord from mechanical injury, and requires that the ends of the wires be taped, to prevent the cotton covering from becoming ignited, in case of an arc or flash in a socket. It is customary to suspend lamps on cords at a height of six feet and six inches from the floor. The result is that when a person reaches up to turn on a lamp, especially if the person is below the average height, there is a strain put upon the cord and, if the strain is carried to the point where the wires are attached to the socket or to the ceiling rosette, the contact is soon broken. The natural result of such construction is, first, heating, and next an arc at the point of contact. The code therefore requires that keyless sockets shall be used as far as practicable, and that in *all* cases the lamp shall be suspended from a knot instead of from a joint or other connection of the wire.

The decorative lamps referred to in Rule No. 32 are what are called "*miniature lamps.*" They are mostly used in decorative and often in temporary work. They have a low voltage, and therefore have to be run in series, to be used on a 100-volt circuit. Though of low voltage they may easily become a source of danger, for they usually take a current of one to one and a half amperes, and, when a circuit is broken, the pressure *across* the *break* is not that of the lamp, but that of the *entire circuit.* The miniature lamps have usually been wired with very small wire, and the sockets for attaching them to the wires are flimsy things, so that they have probably been a source of much trouble; and not being a necessity, the underwriters have eliminated them as ordinarily used from *inside* construction. An unlimited number of rules might be made concerning details of construction, but the rules of the code are only those which seem absolutely necessary. Many of them may at first glance seem severe or trivial, but these very rules are the ones that have been originated to prevent the continuation of practices which have created continual hazards and repeated losses.

CHAPTER XVI

CLASS D, ALTERNATING SYSTEMS. CONVERTERS OR TRANSFORMERS.

TEXT OF THE CODE COVERED BY THIS CHAPTER. CLASS D, ALTERNATING SYSTEMS. CONVERTERS OR TRANSFORMERS. 33. CONVERTERS:—*a*. Must not be placed inside of any building, except the Central Station, unless by special permission of the underwriters having jurisdiction. *b*. Must not be placed in any but metallic or other non-combustible cases. *c*. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial insulating supports.

34. In those cases where it may not be possible to exclude the converters and primary wires entirely from the building, the following precautions must be strictly observed: Converters must be located at a point as near as possible to that at which the primary wires enter the building, and must be placed in a room or vault constructed of, or lined with, fire-resisting material, and used only for the purpose. They must be effectually insulated from the ground, and the room in which they are placed be practically air-tight, except that it shall be thoroughly ventilated to the out-door air, if possible through a chimney or flue.

35. PRIMARY CONDUCTORS:—*a*. Must each be heavily insulated with a coating of moisture-proof material from the point of entrance to the transformer, and, in addition, must be so covered and protected that mechanical injury to them, or contact with them, shall be practically impossible. *b*. Must each be furnished, if within a building, with a switch and a fusible cut-out where the wires enter the building, or where they leave the main line, on the pole or in the conduit. These switches should be inclosed in

secure and fire-proof boxes perfectly outside the building. *c*. Must be kept apart at least ten inches, and at the same distance from all other conducting bodies when inside a building.

36. SECONDARY CONDUCTORS:—Must be installed according to the rules for "Low Potential Systems."

Thus far electric currents have been described only as being analogous to currents of water flowing in a pipe. We have however in electricity to deal with two kinds of currents, "*direct*" currents and "*alternating*" currents. A *direct* current may be compared to a current of water flowing constantly in *one direction* in a pipe. An *alternating* current is one which flows first in one direction and then in the opposite direction. We may form a conception of this action by imagining that we have a cylinder like a steam engine cylinder with a piston in it. Suppose now that we bore a hole in one end of the cylinder and insert one end of the pipe in this hole and that we then lead our pipe around and insert the other end in a hole in the other end of the cylinder. Suppose also our cylinder and pipe are both full of water. If now we push the piston forward we will force the water from one end of the cylinder into our pipe and back into the other end of the cylinder. If we reverse the motion of the piston we will cause the water to flow back through the pipe in the *reverse* direction. By pushing the piston back and forth, we can thus make the current of the water flow alternately in one direction and the other in the pipe. This illustration will serve well enough for our present purpose to illustrate the difference between an alternating and direct current in electricity. In the case of an *alternating* current of electricity we have a pressure or

E. M. F. acting along the wire first in one direction and then in the opposite direction and this pressure causes a flow of electricity or an electrical current first in one and then in a reverse direction. These reversals or alternations may take place very frequently. In ordinary alternating currents for electric lighting, the current alternates or changes its direction from seven thousand to fifteen thousand times a minute according to the speed and design of the dynamo. For most applications of electricity, it is best to use a direct current, as the laws governing the action of direct currents are very simple and thoroughly understood and machines for generating direct currents of electricity and for converting them into power have reached a high degree of perfection. There are however many applications of electricity for which alternating currents possess special advantages

Before we can obtain a clear idea of the object of using an alternating current, we must not only form an idea of electricity as a kind of motion which we can call a current, but we must consider it as a *mode of transmitting energy*. We transform the energy stored up in coal into energy stored up in steam. Then we lead the steam into an engine and transform the energy in the steam into energy in the form of mechanical motion. This energy in turn is applied to our dynamo and there transformed into electrical energy. Next the energy in the form of electricity is transmitted along a wire to some point of application, as for example an incandescent lamp, and there it is again transformed into energy in the form of heat and light. When our energy is stored up in *steam* we can measure the power given to our engine in terms of the *volume* and *pressure* of the steam. The greater the flow of steam to the engine, and the greater the pressure of the steam, the greater the horse power transmitted. In a similar manner we can measure the energy given out by a dynamo to our circuit. The greater the *pressure or E. M. F.* and the greater the *current*, the greater is the *power* given out. In fact, the rate at which work is done by electricity is not only proportionate to the pressure and to the current, but it is in electrical units exactly *equal* to the pressure multiplied by the current. We have seen that the unit of pressure is the *volt* and the unit of the current is the *ampere*. The unit of the electrical power is the *watt*. *The rate at which the energy is being given out to a circuit is equal to the amperes multiplied by the volts, and it is expressed in watts.* For example: an ordinary sixteen candle power lamp requires a current of say one-half an ampere and a pressure of 100 volts. The power consumed would be one-half multiplied by 100 or 50 watts. In electricity, as in steam, we can get the same power by using a *high* or a *low* pressure, but if we raise the pressure of the steam we can get our work with less steam, and if we lower the pressure we must use more steam to get the same amount of work. Just so with electricity. We can get a given amount of electrical work from a dynamo giving a *small current* with a *high pressure* or a *large current* at a *low pressure*, provided we increase the current as we decrease the pressure and decrease the current as we increase the pressure so that the *product of the two* (or the watts) *remains the same.* For example, we may operate a sixteen-candle power lamp with 100 volts and one-half an ampere, or we may by using a suitable lamp get the same candle power with the same amount of electrical power by operating at 50 volts and one ampere.

The electrical pressure used for any particular kind of work depends upon circumstances. We have seen that in transmitting electricity over a conductor the thinner and the longer the wire the greater will be the loss with a given current; and again we have seen that for a given size and length of wire, the greater the current the greater will be the loss. We have just seen that the current required to transmit a given amount of electrical energy depends upon the pressure at which it is delivered, and that we can decrease the current in proportion as we increase the pressure. It follows, therefore, that if we wish to transmit electricity to a *distance* with a *small loss* we can do it in two ways: First, we can use a very *thick wire;* and, second, we can use a *high pressure* (and a correspondingly small current). To appreciate the above statement we have only to remember that the loss of energy is proportionate to the current (not to the pressure), and that the greater the pressure used the smaller will be the current required to do a given amount of work or operate a given number of lamps. In *steam* work we are limited in the pressures we can use for the *strength of our boilers,* In *electricity* we are limited in our pressures by our *insulating materials.* The higher the pressure the greater the strain on the insulation. With high pressure the insulation becomes expensive, and above a certain point it is practically impossible to maintain any insulation at all. When our wires are strung in the air upon glass insulators on wooden poles, we can sometimes go as high as ten thousand, or even twenty thousand volts. Inside buildings, however, such pressures are not permissible, as it is practically impossible to insulate for them. In *inside wiring* for *incandescent lighting* the pressure is limited by the nature of our incandescent lamps. No one has as yet been able to produce an incandescent lamp that will operate satisfactorily and economically at an E. M. F. of more than about 115 volts, and 110 volts is the limit usually set. This means a pressure of 110 volts on our inside wires when we use a two-wire system, and of 220 volts when we use a three-wire system. The advantage of the alternating current in electrical engineering, especially in *electric lighting*, is that its use enables us to operate our *lamps* at a *low pressure*, of say 50 or 100 volts, and at the same time use a *high pressure* on our long *outside lines*, thus saving immensely in the amount of copper required.

This is accomplished by the use of what are called "*transformers*" or "*converters*." The transformer may be defined as a device which transforms a small high pressure current into a large low pressure current, or vice versa. The construction of a transformer is simple. It consists of a core of soft iron wire or sheet iron wound with two independent coils of insulated copper wire. When an alternating current is sent through one of the coils of the transformer, an E. M. F. is set up in the second coil, and if the two ends of the second coil are connected through a lighting circuit, or other low resistance, a current will flow through the circuit or lamps. The current flowing in *one coil* therefore sets up (by an action called "*induction*") a current in the *second coil*, although this coil is independent of and insulated from the first, and the current will flow in the second coil as long as one flows in the first. If the two coils have the same number of turns of wire each, the current induced from the second coil will have the same E. M. F. as the current in the inducing coil, and, as there is but little loss in the transformation (in a good transformer), the two currents will be about equal in strength. We call the coil carrying the inducing current the primary coil and the one carrying the induced current the secondary coil. The circuit by which the current is led to the primary coil is called the "*primary circuit*," and the circuit by which the current is led from the secondary coil to the lamps is called the "*secondary circuit*." In ordinary lighting the *primary* circuit is a "*high potential*" circuit and the *secondary* circuit is a "*low potential*" circuit. If we have twice as many turns on the primary coil of the transformer as on the secondary coil, the pressure in the secondary circuit will be one-half of that of the primary circuit and the current will be twice that of the primary circuit. If our primary coil has ten times as many turns as our secondary coil, the pressure on the secondary circuit will be one-tenth of that on the primary circuit, and the current will be ten times that in the primary circuit, and so on for any ratio of winding. The above statement neglects the losses of transformation, which need not be here considered, except to state that whatever loss there is, is transformed into heat and raises the temperature of the transformer. Naturally the primary coil, having many turns and carrying a small current, is wound with fine wire, and the secondary coil of a few turns and carrying a strong current is wound with coarse wire. As commonly constructed, a transformer is wound for an inducing or primary current of one thousand or two thousand volts and an induced or secondary current for 50 or 100 volts. One example illustrates the advantages of using an alternating system when our central station is at a distance from the lamps. Suppose that we have 200 sixteen-candle-power lamps of 100 volts inside a building, we will install a 200 light transformer. The current given out to the *secondary circuit* at 100 volts will be *100 amperes*. If our transformer transforms from 1,000 to 100 volts, we will then have a current of but *ten amperes* in the *primary* circuit. The current in our outside circuit will therefore be but *one-tenth* of what it would be if we transmitted the current from the station at 100 volts. For a given distance and given loss of energy in our conductors we may therefore use a wire for our street circuit of only $\frac{1}{100}$ the size (or weight per mile) that would be required if we had to tran mit at 100 volts. If we use a transformer with a 2,000 volt primary, the primary current will be but *five* amperes, and we can transmit the same amount of energy the same distance and with the same loss upon a wire of only $\frac{1}{400}$ the size required for transmitting at 100 volts. The saving in copper is therefore enormous.

The coils in a converter or transformer are at present always surrounded by some insulating but *inflammable* material. The wires are usually covered with cotton and further insulated from one another, from the core and from the iron case in which they are placed, by other insulating substances, oil, paper, pitch, shellac, fibre, mica, etc., being most commonly used. Rules Nos. 33, 34 and 35 of section "d" are self-explanatory. They simply require that the transformers shall be inclosed in fire proof cases and shall be so placed that the inflammable material used in their construction cannot, even if ignited, create a hazard; and that the *primary* circuit both *inside* and *outside* the transformer shall be absolutely insulated from both the secondary circuit and the earth. The pressures generally used on primary circuits are high enough to cause instant death to any one who may be unfortunate enough to allow his body to form a part of the circuit, and the necessity of insulating such circuits within buildings, and especially of insulating them from low pressure *lamp circuits,* is too apparent to require explanation. Without such insulation no one could touch an electric lamp or lamp socket without risking his life, and the danger to property would be nearly as great as the danger to life, for the insulation allowable upon a low tension circuit offers little or no protection if submitted to a strain of 1,000 to 2,000 volts. A converter is said to *burn out* when the insulating material surrounding the coils is destroyed by heat. If properly constructed and installed, a converter may burn out without setting a fire, but as the burning out of the converter (especially if filled with oil) may cause a dense smoke, converters should *if possible* be placed *outside* of buildings. Where it is absolutely necessary to install converters in building, as for example where the street mains are underground, the converters should be so installed that no damage from smoke will ensue even if they are burned out.

Rule 36 simply requires that secondary or lamp circuits shall be insulated and protected in the same manner as any other low tension circuits. The code makes no distinction between systems using alternating and direct currents. It simply requires insulation and safe guards *suited to the pressure.* Now that electricity is being distributed on primary circuits at pressures sometimes as high as five thousand and ten thousand volts, the question of insulating primary from secondary circuits is one which will force itself more and more upon the attention of the underwriters. The hazard to life already demands a standard even higher than that required by the code.

CHAPTER XVII.

CLASS E, ELECTRIC RAILWAYS.

TEXT OF THE CODE COVERED BY THIS CHAPTER. CLASS E. ELECTRIC RAILWAYS:—37. All rules pertaining to arc light wires and stations shall apply (so far as possible) to street railway power stations and their conductors in connection with them.

38. POWER STATIONS:—Must be equipped in each circuit as it leaves the station with an *approved* automatic "breaker," or other devices that will immediately cut off the current in case the trolley wires become grounded. This device must be mounted on a fire-proof base, and in full view and reach of the attendant. Automatic circuit breakers should be submitted for *approval* before being used.

39. TROLLEY WIRES:—*a*. Must be no smaller than No. 0, B. & S. copper or No. 4, B. & S. silicon bronze, and must readily stand the strain upon them when in use. *b*. Must be well insulated from their supports, and in case of the side or double pole construction, the supports shall also be insulated from the poles immediately outside the trolley wire. *c*. Must be capable of being disconnected at the power house, or of being divided into sections, so that in case of fire on the railway route the current may be shut off from the particular section and not interfere with the work of the firemen. This rule also applies to *feeders*. *d*. Must be safely protected against contact with all other conductors.

40. CAR WIRING:—Must be always run out of reach of the passengers, and must be insulated with a water-proof insulation.

41. LIGHTING AND POWER FROM RAILWAY WIRES:—Must not be permitted under any pretense, in the same circuit with trolley wires with a ground return, nor shall the same dynamo be used

for both purposes, except in street railway cars, electric car houses, and their power stations.

42. CAR HOUSES:—Must have special cut-outs located at a proper distance outside, so that all circuits within car houses can be cut out at any point.

43. GROUND RETURN WIRES:—Where ground return is used it must be so arranged that no difference of potential will exist greater than five volts to 50 feet, or 50 volts to the mile between any two points in the earth or pipes therein.

In this country electric railways are almost without exception operated at a pressure of about 500 volts. Where there are excessive losses in the conductors, the dynamo voltage is sometimes run up as high as 600 or 700 volts in order to give about 500 volts to distant points on the system, but we may say that it is universal practice to operate street railway motors at from 500 to 550 volts. Electric railway circuits, therefore, come under the class of *high potential* circuits referred to in the code. For this reason, Rule No. 37 requires substantially the same class of construction in street railway stations as in arc light stations, "as far as possible." The rules concerning central stations light and power (Class A) all apply to street railway stations except Rule 7, concerning "testing." With but few recent exceptions, all electric railways in the United States are constructed with what is called a "ground return," *i. e.*, the current for operating the motor flows from one bus bar in the station out on to a system of conductors. From these conductors it flows through the motor, then is led through the axles and wheels of the car and rails, which form a path by which it returns to the station. As the rails are laid in the earth, it follows that one side of the system is grounded. We speak of a "ground return," but the current may be, and often is, led *out* on the *rails* and *back* upon the *overhanging conductor*. The *direction* of the current has no bearing upon the manner of installing the system. It is evident that such a system is not insulated in the ordinary sense of the term. The only insulation required is that necessary to prevent the current from flowing from the wires to the ground without passing through the motors, and to prevent the leakage of current to the conductors of *other* electric systems. The automatic "breaker" referred to in Rule 38 is what is ordinarily called a "*circuit breaker.*" A circuit breaker is in fact an automatic switch which opens the circuit leading out of the station when the current becomes great enough to endanger the dynamos. The circuit breaker performs the same function as a main line fuse in an incandescent lighting circuit, but an automatic switch is better than a fuse for the reason that the overloads are frequent and heavy. The circuit breaker is more certain than the fuse; will open in less time than is required for a fuse to "blow," and it can be set for any desired load according to the machine to be protected. Again, the circuit breaker can be quickly re-set, thus preventing annoying interruption to travel. The construction of a circuit breaker need not be considered here. From an insurance man's point of view, a circuit breaker is simply a safety device to protect the power house.

Conductors of electric railways comprise the feeders, trolley wires and rails. The trolley wires are the bare wires suspended over the middle of the track from which the current is led through the trolley to the car. Feeders are the main wires which conduct the current from the station to the trolley wire. Where the distances are short or the number of cars small, the feeders are sometimes omitted, the current being carried from the station directly to the trolley wire. Where there are many cars or long lines, heavy feeders are used. The rails complete the circuit from the motors to the power house. They are made into continuous conductors by connecting the ends of adjacent rails with copper wires or strips called "bonds." Where the current used is very great, or the distance very long, the rail circuit is sometimes supplemented either by overhead feeders, or by a bare wire laid in the ground alongside the rail. Such a wire is called a "*ground wire.*" Ordinarily a "ground wire" is not a necessity, but the *proper bonding of the rails* is very essential. Section "a" Rule 39, requires a *strong* trolley wire. This is desirable from all points of view. If a trolley wire falls and touches the ground, the current goes direct to the ground, the generators are overloaded, the circuit breakers fly out and the cars stopped until repairs are made. Again, if the trolley wire falls upon a horse or mule, the unfortunate animal completes the circuit and being well grounded through iron shoes, he generally gets enough current to electrocute him. A healthy man seems to be tougher than a horse, but a shock of 500 or 600 volts may under certain conditions seriously injure a man, and if he has a defective heart such a shock may permanently stop its operation.

Section "d" is a regulation that is especially demanded by insurance companies. Many systems of wiring in buildings, as for example telephone, telegraph and clock circuits, use ground returns and the connection between such wires and a trolley wire furnishes a path to ground *within buildings* and over conductors not insulated for high pressures or large enough to stand strong currents. Such connections or "crosses" have caused some very serious fires. Safety is usually sought by suspending one or more guard wires over each trolley wire. The guard wires are light iron wires whose function it is to support any fallen wires of other systems so that they cannot touch the uninsulated overhead railway conductors. Car wiring comprises the conductor from the trolleys to the motors and controlling devices and to the incandescent lamps in the car. The preceding remarks about the pressure of street railway circuits and the consequent danger from shocks sufficiently explains Rule 40.

Rule 41 refers to the use of street railway circuits for furnishing electric lights and power in buildings. This use is prohibited except in power houses and car barns. There are many obvious reasons for this. Where a "ground" return is used it is of course impossible to insulate the conductor from the ground. One side of the system is "grounded" and the other side is separated from the ground by only *one thickness* of insulation. The use of such circuits in buildings, is a hazard to property and a menace to life. There are many reasons why the practice of using street railway circuits for lighting and power in buildings is bad and it is absurd to allow such applications when *high insulation* is demanded upon *low potential* lighting or power circuits. Owing to the varying pressure on street railway circuits, their use for lighting is not often desirable, but if it were permitted they would be extensively used for operating stationary motors, provided it was safe to do so. But it is not safe except in a few isolated exceptional cases, where special precaution can be taken, as for example in a fire-proof building into which the wires are brought directly from street. In general where there is anything to burn, the use of a 500 volt grounded circuit is very improper.

Rule 43 has doubtless been called forth by the trouble experienced by electrolysis. We have spoken of the current as returning to the station by way of the rails, but its path is not necessarily confined to the rails. As the rails are laid in the ground, the earth itself forms a return path and in fact it was once thought desirable to depend on the earth as a part of the return circuit. The current will return along any path that is offered. If there are iron waterpipes, or gas pipes or lead covered cables in the vicinity of the rails, a portion of the current will flow back on these or along any other metallic path. The term "*electrolysis,*" as used in connection with street railway circuits, refers to an action of electric current similar to that which takes place when electricity is used for electro-plating. When a current flows from a rail to an iron pipe, then along the pipe and back to another rail, if the rails and pipes are in a damp place electrolysis will take place; that is to say, the iron of the rails or pipe will be rapidly carried off with the current at the point where it leaves and the rail or pipe will be eaten away, as a metal plate is eaten away in an electric battery or in a plating bath. The greater the current the greater will be the amount of iron carried away in a given time. The result of this action is the rapid pitting and corrosion of water and gas mains by the current of electric street railways using a ground return. There are two remedies for electrolysis: First, we may use an *overhead* instead of a *rail* return for the current. This is very expensive and not very practical, as it requires twice as many overhead wires and makes very complicated and unsightly overhead construction, especially crossings and turn-outs. The whole problem is too long to discuss fully here. Electric railways may cause a hazard by eating through gas mains and igniting the gas, or by destroying the insulation of underground electric cables leading into buildings.

Rule 43 is apparently an attempt to limit the damage from electrolysis. By limiting the drop in volts (or the loss in our return circuit) we may decrease the danger of the current straying from rails to pipe, etc., and thus lessen the danger of interference with other systems. But, in the light of recent experience, the enforcing of Rule 43 would not go far toward removing these troubles. The loss of pressure (or difference of potential), allowed by Rule 43, is too great to render the rule of any value, but it is to be hoped that, at no distant date, legislation or the action of the courts will demand some remedy that will prevent the damage to property which is now going on all over the country.

CHAPTER XVIII.

CLASS F, STORAGE OR PRIMARY BATTERIES.

TEXT OF THE CODE COVERED BY THIS CHAPTER. CLASS F. 44. STORAGE OR PRIMARY BATTERIES:—*a*. When current for light and power is taken from primary or secondary batteries, the same general regulations must be observed as applied to similar apparatus fed from dynamo generators developing the same difference of potential. *b*. All secondary batteries must be mounted on *approved* insulators. *c*. Special attention is directed to the rules for rooms where acid fumes exist. *d*. The use of any metal liable to corrosion must be avoided in connections of secondary batteries.

DEFINITION. RULE 44. STORAGE OR PRIMARY BATTERIES:— Section *b*. Insulators for mounting secondary batteries to be *approved* must be non-combustible, such as glass, or thoroughly vitrified and glazed porcelain.

The practical difference between a *primary* and a *storage* battery is pretty well indicated by the terms "Storage" and "Primary." A primary battery, like a dynamo, is a source of electrical energy. In fact, it can *more* properly be called a source of electrical energy than a dynamo, as the current is generated in a primary battery without the application of any external force. A storage battery, on the other hand, is simply a device by which the electric energy generated in a dynamo or primary battery is *stored*. The analogy may be a little far fetched, but we may use our comparison between a current of water and a current of electricity by saying that a dynamo corresponds to a pump driven by some prime mover, a primary battery corresponds to a chemical fire engine, which will maintain a flow of water as long as the supply of chemicals is maintained, and a storage battery corresponds to an elevated tank, out of which we can get a flow of water only after it has been filled up by our pump. The difference between a primary and a secondary battery does not have any special bearing upon the rules concerning their installation and care, for two reasons: first, a primary battery is such an expensive source of obtaining electricity that it is never used for producing electricity for light and power; again, if primary batteries were so used the rules regulating their installation and use would be the same as for storage batteries.

It may, however, be of passing interest to describe a little more fully the difference between the two kinds of batteries. If we take two plates of two dissimilar metals and immerse them (without their coming into contact with one another) in a liquid which has a chemical affinity for either one of the metals, we have a *primary cell.* If we connect the two plates outside of the liquid with a wire or other conductor, an electric current will flow through the circuit thus formed, *i. e.*, it will flow from plate number one to plate number two through the liquid within the cell, and from plate number two to plate number one through the wire outside the cell. The pressure or electro-motive force of the cell will depend upon the metals selected for the plates. For any particular cell the strength of current which it gives out is determined by the E. M. F. of the cell and the resistance of the circuit. The circuit is made up of three parts—the liquid, the plates themselves, and the external conductor. The length of time that the current will be maintained depends upon the size (*i. e.*, weight) of the plates. One of the plates is gradually eaten away by the action of the cell. The electrical energy in the circuit is a reappearance of the energy of chemical action in the cell, and naturally the more metal there is to maintain the chemical action the more electricity will be given out before the cell is exhausted. Carbon may be used instead of metal as one plate, or "electrode" of a cell, but the other plate must be of metal, and it is the metal plate which is consumed.

A "battery," strictly speaking, is a group of "cells," but the words cell and battery are used indiscriminately by nearly everyone. We hear a person speak of a battery of ten cells, and in the next breath he speaks of using ten cells of battery. The connection in which the words are used generally leaves no doubt as to whether one or more cells is meant. One of the most common forms of primary cells has plates of zinc and carbon, the liquid being varied according to use to which the cell is to be put. The ordinary well known "gravity" or "blue stone" cell has plates or electrodes of zinc and copper. In either of these batteries it is the *zinc* which is consumed, and the more electricity there is given out the faster the zinc is consumed. The poor economy of a primary battery as compared with a dynamo is apparent when we consider that it requires a constant supply of coal to keep up a supply of electricity from a dynamo, and a constant supply of zinc (and incidentally of chemicals) to keep up the supply of electricity from a primary battery. As we might expect, therefore, a primary battery is too expensive for use when much electricity is required, as for light and power. It is cheaper to use an outfit that burns coal than one that burns zinc. The metal and chemicals required to produce an electrical horse-power from the best primary battery on the market will cost one hundred times as much as the fuel required to produce an electrical horse-power with a very ordinary steam plant and dynamo.

A storage battery, as its name implies, simply stores up the electricity given to it by a dynamo, and gives it out again when wanted, minus of course a portion which is lost in this as in all other transformations of energy. This loss is usually from five per cent. to twenty per cent. of the amount put into the battery, but it may be more if the battery is a poor one or badly handled; fifteen per cent. is usually allowed as the average loss with a first-class battery under fair conditions. We have said that a battery *stores electricity.* Apparently it does, but in reality it does not. It does store up *energy* and gives it out in the *form* of electricity. The action is this: A storage battery, secondary battery, or accumulator (as it is variously called), is much the same as any primary battery except that the plates, instead of being made of two dissimilar metals, are made of the same metal. All metals, however, will not work in a storage battery. All the storage batteries which have thus far been enough of a success to be put into practical use have had plates of lead or of a combination of lead and oxide of lead. Two lead plates or groups of plates immersed in any liquid will not form a primary battery, but if we take two lead plates and immerse them (without touching one another) in a dilute solution of sulphuric acid and then send an electric current through the combination, leading it into one plate and out of the other, the action of the current will in time change the chemical condition of the plates.

The current (which must be a direct, not alternating, current) will gradually change the plate by which it enters the cell into a red oxide (or peroxide) of lead, and the other plate, or the one by which the current leaves the cell, will be reduced to soft (or spongy) metallic lead. When the plates have reached this condition, we have in reality two plates of dissimilar materials, one of *lead* and one of *oxide of lead*, and if they are now connected outside the liquid by a wire or other conductor, a current will be given out the same as from a primary battery. This current will flow not as in a primary battery until one of the plates is consumed, but until both plates have again undergone a chemical change and are again identical in their chemical composition. To "*form*" a battery, *i. e.*, to get it into working condition, requires several charges and discharges, but we will not encumber the present book with more detail or theory than is necessary to give a practical idea of how the battery works. We have seen that in a primary battery there is an oxidation which consumes the active plates, as coal is consumed by oxidation; in fact, there is *combustion*. In a storage battery the energy is not produced by combustion, but is produced by an outside source of energy. The action of repeatedly charging and discharging a storage cell is accompanied by a repeated oxidizing and deoxidizing of the plates. A storage battery is therefore a true battery. While it practically stores electricity, the real action is, first a transformation of electrical into chemical energy and then a reverse action in which chemical action produces electricity in much the same way as in a primary battery.

We have said that the plates in a storage battery are not consumed. This is true only in comparison with a primary battery. While the plates after one charge and discharge come back to substantially their original condition, continued charging and discharging eventually destroys the plates. The life of the plates depends upon how often the battery is charged and discharged, how long the action is continued, and upon the strength of the charging and discharging current. An excessive current, either in charging or discharging, or too prolonged a charge or discharge, even with a moderate current, rapidly reduces the life of the plates. Storage batteries must be frequently examined and cleaned, and the acid must be tested and kept at proper specific gravity. Batteries should therefore be accessible, and should be so placed that they can be handled without any undue slopping of acid, which rapidly turns woodwork into a good conductor. Section "b" of Rule 44 is important. In all storage battery plants inside buildings the batteries should be mounted upon *properly designed oil* insulators. An ordinary porcelain knob, or even a double petticoat glass insulator, such as is used for supporting wires on poles, is of but little use for insulating a storage battery. A storage battery (particularly while it is charging) gives off copious acid fumes, and everything near a battery is soon covered with a film of moisture which is an excellent conductor. As moisture condenses rapidly on glass or porcelain the ordinary insulator soon fails to insulate.

Section "c" of Rule 44 is called forth by this same well-known property of a storage battery. The acid fumes will corrode any metal except lead, so that electrical machinery or instruments should not be placed near a battery unless the battery is in a separate room, or closet, which is ventilated into a separate room, or, better, into the open air

Section "d" practically prohibits the use of any metal for battery connections except lead. The best way to join cells is to have the plates provided with long strips or lugs of lead, and to make the connection with solder, far enough away from the acid so that they will stay reasonably dry. As, however, such a permanent connection might discourage the average attendant from disconnecting the cells when necessary for inspection or cleaning, some kind of a clamp is usually preferred. The device which comes the nearest to giving a satisfactory joint, and at the same time one that can be readily disconnected, is the lead-covered bolt. The lead lugs are bolted together by a short brass bolt passing through holes in the lugs; this bolt is threaded on both ends, and each end is provided with a brass, lead-covered bolt. The result of this arrangement is that when the bolts are drawn up tightly the lugs are clamped together, and if the joint is carefully made and kept tight it leaves nothing but lead exposed to the fumes of the acid. For general use this joint gives the best results of anything yet devised for the purpose.

A battery should always be protected by safety devices the same as a dynamo. Circuit breakers and fuses are both used for this purpose.

Section "a" of Rule 44 explains itself. It is a rule which has been often neglected in the past with disastrous results, the battery itself usually being the chief sufferer. It is, however, a rule that should be rigidly enforced.

CHAPTER XIX.

MISCELLANEOUS.

Text of the Code Covered by this Chapter. Miscellaneous:—45. *a.* The wiring in any building must test free from grounds; *i. e.*, each main supply line and every branch circuit shall have an insulation resistance of at least 25,000 ohms, and should have an insulation resistance between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.,) of not less than the following:

Up to	10	amperes	4,000,000
"	25	"	1,600,000
"	50	"	800,000
"	100	"	300,000
"	200	"	160,000
"	400	"	80,000
"	800	"	22,000
"	1,600	"	11,000

All cut-outs and safety devices in place in the above. Where lamp sockets, receptacles, and electroliers, etc., are connected, one-half of the above will be required. *b.* Ground wires for lightning arresters of all classes, and ground detectors, must not be attached to gas pipes within the building. *c.* Where telephone, telegraph or other wires connected with outside circuits are bunched together within any building, or where inside wires are laid in conduit or duct with electric light or power wires, the covering of such wires must be fire-resisting, or else the wires must be inclosed in an air-tight tube or duct. *d.* All conductors connecting with telephone, district messenger, burglar-alarm, water-clock, electric time, and other similar instruments, must be provided near the point of entrance to the building with some protective device which will operate to shunt the instruments in case of a dangerous rise of potential, and will open the circuit and arrest an abnormal current flow. Any conductor normally forming an innocuous circuit may become a source of fire-hazard if crossed with another conductor, through which it may become charged with a relatively high pressure. (See Definitions.) The following formula for soldering fluid is suggested:

Saturated solution of zinc....................5 parts
Alcohol....................................4 parts
Glycerine..................................1 part

DEFINITIONS. RULE 45. WIRE PROTECTORS:—Protectors must have a non-combustible, insulating base, and the cover to be provided with a lock similar to the lock now placed on telephone apparatus or some equally secure fastening, and to be installed under the following requirements: 1. The protector to be located at the point where the wires enter the building, either immediately inside or outside of the same. If outside, the protector to be inclosed in a metallic waterproof case. 2. If the protector is placed inside of building, the wires of the circuit from the support outside to the binding posts of the protector to be of such insulation as is approved for service wires of electric light and power, and the holes through the outer wall to be protected by bushing the same as required for electric light and power service wires. 3. The wire from the point of entrance to the protector to be run in accordance with rules for high potential wires; *i. e.*, free of contact with building, and supported on non-combustible insulators. 4. The ground wire shall be insulated, not smaller than No. 16 B. & S. gauge. This ground wire shall be kept at least three (3) inches from all conductors, and shall never be secured by uninsulated double-pointed tracks. 5. The ground wire shall be attached to a water pipe, if possible; otherwise may be attached to a gas pipe. The ground wire shall be carried to and attached to the pipe outside of the first joint or coupling inside the foundation walls, and the connection shall be made by soldering, if possible. In the absence of other good ground, the ground shall be made by means of a metallic plate or a bunch of wires buried in a permanently moist earth.

MATERIALS:—The following are given as a list of non-combustible, non-absorptive, insulating materials and are listed here for the benefit of those who might consider hard rubber, fiber, wood, and the like, as fulfilling the above requirements. Any other substance which it is claimed should be accepted, must be forwarded for testing before being put on the market. 1. Thoroughly vitrified and glazed porcelain. 2. Glass. 3. Slate without metal veins. 4. Pure sheet mica. 5. Marble (filled). 6. Lava (certain kinds of). 7. Alberene stone.

WIRES:—The following list of wires have been tested and found to comply with the requirements for an approved insulation under Rule 10 (*a*), Rule 12 (*d*), and Rule 18 (*a*). Acme; Ajax; Americanite; Bishop; Canvasite; Clark; Columbia; Crescent; Crown; Edison Machine; Globe; Grimshaw (white core); Habirshaw (red core); Kerite; National India Rubber Co. (N. I. R.); Okonite; Paranite; Raven Core; Safety Insulated (Requa white core, Safety black core); Salamander (rubber covered); Simplex (caoutchouc); United States (General Electric Co.) None of the above wires to be used unless protected with a substantial *braided* outer covering.

We have already seen that wires of *opposite polarity* must be insulated from *one another*, and that *all* wires must be insulated from the *ground*. The question now arises: "*What is insulation?*" The term insulation is a relative one. Every conductor, even one of copper, offers a measurable resistance to a flow of current, and every insulator, even rubber, permits a measurable amount of electricity to pass through it. A wire covered with a thin covering of rubber may be well insulated to withstand a pressure of 100 volts, but poorly insulated for a pressure of 1,000 volts. What then is proper insulation? The insulating properties of the various rubber compounds used to cover wire vary very greatly when the insulation is new, and much more when the insulation is old; the covering of wires is often injured or destroyed by the carelessness of workmen; and, again, every device attached to a circuit offers some opportunity for leakage. The *thickness* of *insulation* on wires cannot therefore be taken as a standard. The only practical standard is an electrical standard. In any system of conductors the insulation of the wires must present a certain resistance to the flow of current from the positive to the negative conductors, along any path, except the path provided by the wires themselves and the lamps, motors, etc., connected to them. This resistance is called the *insulation resistance* of the system. It is measured in ohms.

We must bear in mind that our electricity does not try to leak off into space or into the ground, but that whenever there is a difference of electrical pressure between two wires, this pressure is always trying to send a current *from one wire to the other*. The current which will flow depends upon the total resistance of all paths between the two wires. If the two wires come into metallic connection, they are as we say "*crossed*," and we have what is called a *short circuit*. If *one* of the wires comes into electrical contact with the earth, then that wire is "*grounded;*" we then have nothing separating the wires electrically except the insulation of the *other* wire. If now the *second* wire becomes connected electrically to the earth, we have the two wires connected electrically *through* the earth, and a leakage takes place. The amount of this leakage of course depends upon the resistance of the contacts between the wires and the earth. A ground *on one wire* is only dangerous as it is a step, half way, toward the crossing of wires of opposite polarity, but when any wire in a system is grounded, a second ground appearing anywhere on *any* wire of *opposite polarity*, creates a cross and a leak.

When the resistance between a wire and the ground is very low, we say we have a "*dead ground*," and when we have a dead ground on both poles of the system we have a "*short circuit;*" and as a result, a leakage which is only limited by the capacity of our dynamos and engines. The code requires an insulation resistance of at least 25,000 ohms on any main or branch circuit. This rule is applicable only to the low potential circuits used for incandescent lighting. The code, as we have seen, defines low potential circuits as those carrying a pressure of 300 volts or less. This insulation, *i. e.*, 25,000 ohms, is the least that is allowed on any circuit. Why this standard is mentioned in the code is not apparent, since in order to get the insulation required by the code on any *system* of conductors, the insulation on any *individual circuit* must be much better than 25,000 ohms. The more circuits there are in any system of wiring, the lower will be the insulation resistance of the system, supposing a given resistance for each circuit. This is easily understood. If we have two wires of opposite polarity, and provide a path for the current to flow between them, we will have a certain resistance opposing the flow, whether the path be good or poor; whether it is formed by a conductor or an insulator. If now we provide a second path just like the first, the total resistance to the flow will be but one-half what it was before. Each and every time that we add another path, we lower the total resistance between the wires. When we have a number of lamps or motors forming separate paths for the current to flow from the positive to the negative conductors of a system, we say that the lamps or motors are in "multiple arc," or in "*multiple.*" With a given pressure, the more lamps there connected the less will be the total resistance of the circuit thus formed, and the greater will be the current. With insulation it is the same. Every foot of wire added to a system decreases the insulation resistance of the system and increases the leakage of current.

If we have *two* circuits, each having an insulation resistance of 1,000,000 ohms, their *combined* insulation resistance will be 500,000 ohms. If we have *ten* such circuits, the insulation resistance of the system will be 100,000 ohms, and if we have 100 such circuits, the total insulation resistance of the system will be but 10,000 ohms. With a given kind of construction and of insulation covering for our wire, we can figure that the more wire there is used in any system of conductors, the less will be the insulation resistance. It might be desirable (if it were possible) to have an arbitrary standard for the insulation resistance of all plants using a certain voltage, but it is not possible to work to such a standard, for we are limited on large plants by the quality of the materials available for insulation, and the adoption of such a standard would be equivalent to a lowering of the standard for small plants, which is by no means desirable, experience having demonstrated that the best insulation that can be obtained from materials in the market is none too good.

It is not feasible to make the standard depend upon the total length of wire in a system, owing to the difficulty of finding out this amount and to the fact that every cut-out and socket attached to the system adds a leakage point. The code, therefore, makes the insulation resistance required depend upon the *number of lamps connected*, or, what is the same thing, upon the *amperes* of current in the whole system. Allowing about ten amperes to a branch circuit, the table given under section "a," Rule 45, corresponds to an average insulation resistance of from about 2,000,000 to 4,000,000 ohms per circuit, according to the size of the plant. Every device attached to the system lowers the insulation resistance so that the code permits a resistance of one-half this amount when the lamps, fixtures, etc., are in place. We may, therefore, say that the standard of the code is 1,000,000 to 2,000,000 ohms per circuit, according to the size of the plant, if we assume the circuit to average ten amperes each. Since it is now customary to allow only ten to twelve lamps or five to six amperes to a branch circuit, the standard really amounts after all to an average of 3,000,000 to 4,000,000 ohms per circuit. It is pretty fair practice to require 1,000,000 ohms or one "megohm" on *each and every* circuit, and a total insulation resistance on the entire system at least equal to that called for in the code. If no circuit is less than one megohm, many of the circuits will show several megohms, so that the average will be much more than a megohm, and the entire system will test out all right.

The requirements of Rule 45, section "b," have been referred to before in the code. A gas pipe may form a very poor path for a current to take to the earth, and if the piping in the building has been disconnected from the street mains, the pipe may not provide any path at all to the earth. It is certainly poor policy to provide a path to conduct lightning to a network of piping in a building where there is no assurance that there is a path *from* the piping to the *earth*. Again, it is obvious that we may be inviting trouble by leading lightning and perhaps heavy dynamo currents to a pipe filled with gas. The object of section "ç" of Rule 45 is to prevent fires from being caused by the accidental crossing of electric light or power wires with other wires which themselves carry harmless currents (*i. e.*, small currents of very low pressure), and which do not, under normal conditions, require high insulation. The crossing of light or power wires, either in the street or inside buildings, with telephone, telegraph, electric clock wires, etc., may, if there is no protecting device, quickly send a current through them that will heat them red hot, or even cause them to melt. The wires used for bells, electric clocks, etc., are commonly covered with a cotton wrapping, which is often saturated in paraffine, and they are laid directly upon woodwork. Crosses between electric light and power wires and wires of the class above referred to may be and often are sources of greater hazard than crosses between electric light or power wires. Even the rubber compounds used to insulate wire are often inflammable, and the rules to prevent the use of insulation that will ignite and carry flame should be observed wherever it is possible.

This matter of inflammable covering for wires will undoubtedly receive more attention in the future than it has received in the past, and the time will surely come when all wires will be of such material, or so insulated, that they cannot carry flame. Section "d" requires the use of a device to prevent the class of conductors, above referred to, from receiving from a light or power circuit a current sufficient to overheat them, or from becoming alive from contact with conductors of a system having a pressure high enough to be dangerous to life. The "*protectors*" commonly used are fusible cut-outs having some kind of fuse which will open the circuit quickly upon the flow of a small current. These devices are described in the "Definitions" as completely as it is possible to describe them in this brief work.

The securing of high insulation and of maintaining it is the great problem of the constructor. The code shows what is required; the way to secure it is to use the right material and methods and good workmanship and to test the insulation carefully during construction and at each stage of the work. The code gives a list of wires that we are *permitted* to use. These wires have about all grades of insulation on them from the best to about the poorest that can be sold. Experience alone determines what wire or insulating material is good enough for or best adapted to each piece of construction. In installing a plant the insulation of each circuit should be tested as it is run before anything is connected to it. The wiring in the fixtures should be tested before the fixtures are put in place, and it is well to test them again after they are in place but before they are connected to the circuit. Finally each and every circuit should be tested after everything is complete and everything in place except the lamps. In this manner it is easy to secure proper insulation provided proper materials are used, and by making periodical tests and keeping a record of the measurements we can always tell the condition of the insulation and can readily maintain the required standard.

CHAPTER XX.

THE 1896 EDITION OF THE CODE.

Since Chapter XIX was written the code has been revised, and the revised edition, dated January 1st, 1896, has been distributed. We would suggest that those of our readers who are interested in watching the evolution of the code compare the code of 1895 with the code of 1896 *section by section*. Such a comparison made upon the publication of each new edition will be a great help to any one who wishes to keep in touch with the electrical inspectors. The code of 1896 differs but little from the preceding edition, and the changes consist for the most part of the addition of certain specific requirements to the general requirements of the earlier edition. In the preceding edition the "*Definitions*" which explained the rules were printed as an appendix at the end of the code. In the present edition these definitions are incorporated into and made a part of the rules themselves, a change which will be a great help to those using the code in practical work and to those who wish to glance through it occasionally to find out what is required for a special kind of construction. Every one who refers to the code should have a copy of this edition. The edition of January 1st, 1896, opens with a page of "General

Suggestions." These suggestions cover the broad principles of the code to which we have endeavored to call special attention in our articles. Following are the suggestions which we believe will be readily understood and appreciated by our readers without comment on our part, but it should be noted that they show clearly how thoroughly the underwriters appreciate the fact that safety is to be secured only by *intelligent design* and careful and *honest workmanship:*

General Suggestions:—In all electric work conductors, however well insulated, should always be treated as bare, to the end that under no conditions, existing or likely to exist, can a grounding or short circuit occur, and so that all leakage from conductor to conductor, or between conductor and ground, may be reduced to the minimum. In all wiring special attention must be paid to the mechanical execution of the work. Careful and neat running, connecting, soldering, tapping of conductors and securing and attaching of fittings, are especially conducive to security and efficiency, and will be strongly insisted on. In laying out an installation the work should, if possible, be started from a center of distribution, and the switches and cut-outs, controlling and connected with the several branches, be grouped together in a safe and easily accessible place, where they can be readily got at for attention or repairs. The load should be divided as evenly as possible among the branches, and all complicated and unnecessary wiring avoided. The use of wireways for rendering concealed wiring permanently accessible is most heartily endorsed and recommended; and this method of accessible concealed construction is advised for general use. Architects are urged, when drawing plans and specifications, to make provision for the channeling and pocketing of buildings for electric light or power wires, and in specifications for electric gas lighting to require a two-wire circuit, whether the building is to be wired for electric lighting or not, so that no part of the gas fixtures or gas piping be allowed to be used for the gas-lighting circuit.

We believe we are justified in concluding from the above "Suggestions" that what are most needed in the electric art are, first, the use of more brains in the designing of plants and systems of conductors; and, sccond, better workmanship. Better workmanship can be obtained by more thorough inspection and by establishing some standard of skill for workmen so that intelligent and careful wiremen shall be better paid, and the men who are not mechanics shall either become laborers or go into some other line of work where their carelessness will not endanger the lives and property of others. As the revised code contains no *radical* changes we will not review the entire text, but will simply call attention as briefly as possible to the changes that have been made. We will take these up under the various "Classes" of work in the order given in the code.

"*Class A, Central Stations.*"—Under Rule 1 "Generators," section "b" now reads:

b. Must be insulated on floors or base frames, which must be kept filled to prevent absorption of moisture, and also kept clean and dry. Where frame insulation is impossible, the inspector may, in writing, permit its omission, in which case the frame must be permanently and effectively grounded.

This change is made to allow and regulate the use of "*direct coupled*" dynamos, *i. e.*, dynamos which are coupled direct to an engine without the use of belts or gears, the armature of the dynamo being mounted directly upon the engine shaft. An engine is always connected (electrically) to the earth so that it is difficult to insulate the frame of a dynamo from the earth when the dynamo and engine are direct coupled. It is therefore considered better practice (when the voltage of the dynamo is not excessively high) to depend upon the *insulation of the conductors* of the dynamo and not attempt to insulate the frame or body of the dynamo from the earth. If the frame of the dynamo is effectively grounded, any defect in the insulation of the dynamo will be discovered by the ground detector or by an insulation test made upon the conductors of the system. As there are no safety devices between the conductors of a dynamo and its frame, it follows that the frame should either be thoroughly insulated or else thoroughly grounded. Direct coupled machines are now the rule rather than the exception in isolated plants, and the above rule is a formal approval of what has been common practice for two or three years.

Rule 6, "Lightning Arresters," section "d," now reads:

d. Must be so constructed as not to maintain an arc after the discharge has passed, and must have no moving parts. It is recommended to all electric light and power companies that arresters be connected at intervals over systems in such numbers and so located as to prevent ordinary discharges entering, over the wires, buildings connected to the lines.

The clause "must have no moving parts" is inserted to shut out the use of electro-mechanical devices which are all liable to get out of order and nearly all of which have to be re-set after one or after a few discharges in order to give protection against the next discharge. The placing of arresters at intervals over a system of outside conductors is ordinary engineering practice. It is absolutely essential in order to get even moderate protection. It has been clearly shown that lightning may at any time or place take a *difficult* path to the earth rather than travel *a distance* on a wire to get to an *easy* path. In practice this means that lightning may go to the ground through a combination fixture in a residence rather than go a *few hundred feet* to a lightning arrester. The nature of the locality determines where and how far apart arresters should be placed on any individual system.

Under Rule 8, "Motors," this section has been added:

d. Must be, when combined with ceiling fans, hung from insulated hooks, or else there shall be an insulator interposed between the motor and its support.

This rule is to provide for the insulation of motors used to run the horizontal fans now much used in restaurants, etc. It is evident without argument that fixtures carrying these motors should be insulated just as much as fixtures carrying incandescent lights.

Class B, High Potential Systems.—Under Rule 10, "Outside Conductors," section "a," the following clause is added:

A wire with an insulating covering that will not support combustion, will resist abrasion, is at least $\frac{1}{16}$ of an inch in thickness and thoroughly impregnated with a moisture repellant, will be *approved* for outside, overhead conductors, except service wires.

This rule simply sanctions what has for a long time been common practice, *i. e.*, the use of "*weatherproof*" wire on pole lines, with rubber-covered wire for services (or wires running into buildings). Practically, the *only* insulation that can be expected on a circuit run on poles is the insulation afforded by the *glass insu-*

lators. Rubber covering on wires has no life when exposed to the weather, and in ordinary construction it will not maintain insulation between the wire and an insulator. The pressure of the tie wire and the swinging of the conductor soon destroy the insulation of any covering at the insulator, which, as far *as the conductor itself is concerned*, is the *only* place where insulation is *needed.* The only advantage of using anything but a bare wire on a pole line is to prevent damage from accidental crossing with *other wires.* However, considering the number of fires that have been caused by such "crosses," it appears desirable to have *some* covering for wires. The first requirement in this covering is *durability*, and as "weatherproof" insulation seems to be more durable than rubber insulation for outdoor work, and as weatherproof wire is but little more expensive than bare wire, it is almost universally used on pole lines. As a matter of fact, there is not much insulation in *cotton braid* and *black paint.* We should depend upon our *construction* and *not* upon the *covering of the wire* for insulation. Much weatherproof wire is no better than bare wire except when *perfectly dry*, and it should always be treated as bare wire.

Under Rule 12, "All Interior Conductors," a new section has been added, as follows:

h. Must be protected from mechanical injury, when necessary, on side walls by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top, and extending not less than five feet from the floor. Where crossing exposed floor timbers in cellars or rooms, the conductors must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness.

The first part of this section is a very essential rule. It should, of course, be understood that the wires are led through the top of the boxing and through the bottom of the boxing, when the boxing has a bottom, in incombustible insulating tubes.

Under Rule 13, "Arc Lamps," section "f," the following is added:

Arc lamps, when used in places where they are exposed to flyings of easily inflammable material, should have the carbons enclosed completely in a globe in such manner as to avoid the necessity for spark arresters. For the present, spark arresters will not be required on so-called "inverted arc" lamps.

Spark arresters were introduced into use at a time when all arc lamps were "*open*" lamps, *i. e.*, so built that the top of the globe was open. Within the past two or three years, "enclosed lamps," *i. e.*, lamps having a metal case enclosing the works and coming down and surrounding the top of the globe, have come into almost general use for inside lighting, and such lamps should *always* be used in *new* installations in buildings. The "*inverted arc*" lamps referred to are lamps in which the light, instead of being thrown downward as in ordinary direct current arc lamps, is thrown upward against a reflector, so that the lighting is done entirely by *reflected* light. These lamps are very desirable for some classes of lighting, where it is desirable to remove the arc itself from the line of sight—though they have thus far been but little used in this country. The code allows their use as now constructed without arresters "*for the present*," which means that the underwriters are not yet ready to either approve or condemn the existing forms. The language used in the code in this connection reminds us to recommend our readers to at all times note very closely the *wording* of the code in order to distinguish between what *may*, what *should* and what *must* be done.

CHAPTER XXI.

EDITION of 1896. (CONCLUSION.)

Class C, Low Potential Systems.—Under section 18, "Conductors," Rule "d" requiring one foot of space between high and low potential conductors wherever they cross one another, is omitted and this rule added:

f. Must be protected from mechanical injury, when necessary on side walls, by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top, and extending not less than five feet from the floor, or by an iron-armored or a metal-sheathed insulating conduit sufficiently strong to withstand the strain it will be subjected to, the inner insulating tubing to extend one-half inch beyond the ends of the metal tube, which must extend not less than five feet from the floor. When crossing exposed floor timbers in cellars or rooms, the conductors must be attached by their insulating supports to the under side of a wooden strip not less than one-half inch in thickness and not less than three inches in width.

This rule is the same one that has been added under section "b" "High Potential Systems," except that for low potential circuits *armored conduit* is allowed in place of boxing.

Under section 19, "Special Rules," Rule "i" now reads:

i. When from the nature of the case it is impossible to place concealed wire on non-combustible insulating supports of glass or porcelain, the wires may be fished on the loop system, if incased throughout in *approved* continuous flexible tubing or conduit. American Circular Loom Tubing is approved for use under this rule.

This last clause is an addition.

In section 20, "Mouldings," Rule "c" now reads as follows:

c. Must be made of two pieces, a backing and capping so constructed as to thoroughly incase the wire and provide a one-half-inch tongue between the conductors, and a solid backing, which, under grooves, shall not be less than three-eighths of an inch in thickness, and must afford suitable protection from abrasion. It is recommended that only hardwood moulding be used

It will be noted that three-eighths of an inch of wood is required between the wires and the wall or ceiling. The preceding edition of the code was silent on this point, but the earlier editions required one-half an inch, which made a rather heavy, clumsy moulding. The last clause in Rule "c" is an addition.

In section 21, "Special Wiring," Rule "d" the following clause is added:

In damp places switches and cut-out blocks must be mounted on porcelain knobs.

In section 22, "Interior Conduits," the section now opens as follows:

The American Circular Loom Company tube, the *brass-sheathed* and the *iron-armored* tubes made by the Interior Conduit and Insulation Company, the *iron-armored* tube made by the Builders' Insulating Company, of Lynn, Mass., the *iron-armored* tube made by the Clifton Mfg. Co., of Boston, and the Vulca tube, are approved for the class of work called for in this rule.

Rule "e" of this section now reads as follows:

e. Must not be supplied with a twin conductor or two separate conductors in a single tube, except in an *approved* iron or steel-armored conduit. The use of approved wires of opposite polarity, either separate or twin conductor, in a straight conduit installation, is allowed in *approved* iron-armored or steel-armored conduits, but not in any of the other approved conduits. Iron or steel-armored conduit to be approved must fulfill the following specifications: 1. Must not be seriously affected externally by burning out a wire inside the tube when the iron pipe is connected to one side of the circuit. 2. When bent with a sag of one foot in the middle of a ten foot length, and filled with water, must have an insulation resistance between the water and the iron pipe of one megohm after three days, temperature being 21 degrees Centigrade (70 degrees Fahrenheit). 3. The insulating material removed from the tube must not absorb more than ten per cent. by weight, of water after one weeks' immersion. 4. The insulating material must not soften at a temperature below 70 degrees Centigrade (158 degrees Fahrenheit), and must leave the water in which it is boiled practically neutral. 5. The insulating material must not become mechanically weak after three days' immersion in water.

All of this is very specific and clear, but not very consistent with a preceding statement which is still retained in the code and which reads as follows:

The object of a tube or conduit is to facilitate the insertion or extraction of the conductors, to protect them from mechanical injury, and as far as possible, from moisture. Tubes or conduits are to be considered merely as raceways, and are not to be relied on for insulation between wire and wire, or between the wire and the ground.

In view of the new requirements and the quality of the conduits now on the market, it will be interesting to watch for reports of the Underwriters' Electrical

Bureau, to see *what makes* of iron conduits are *approved*. The practice of running two wires in one iron tube is the best in *most* cases and is the *only* allowable method in *many* cases—as for example when alternating currents are used and in modern steel construction fireproof buildings. We believe, however, that the high standard of insulation required for the lining of a tube is out of all reason; since there is no method for making such insulation *at joints*. In view of the fact that the question of using *any lining at all*, except to prevent rust, is still under discussion, we believe that the conduit should, for the present at least, be considered as a *hole* and nothing else. Such a treatment ought to develop the manufacture of good insulated wire and will not prevent anyone from putting another insulation around his wire if he sees fit. We do not think an insulating lining will injure a conduit, and, for that matter, it would do no harm to run the conduit on porcelain insulators, but we think the code should be consistent, and there is a conduit now on the market which is all right if people will only pay for it and use it.

In section 23, "Double Pole Cut-outs," Rule "f," which requires that the cut-out block be stamped with the maximum safe carrying capacity, is omitted.

In section 27, "Fixture Work," under Rule "a," it is required that insulating joints be placed as close as possible to the ceiling and the following is added:

It is recommended that the gas-outlet pipe be protected above the insulating joint by a non-combustible, non-absorptive, insulating tube having a flange at the lower end, where it comes in contact with the insulating joint, and that where outlet tubes are used, they be of sufficient length to extend below the joint, and that they be so secured that they will not be pushed back when the canopy is put in place. Where iron ceilings are used, care must be taken to see that the canopy is thoroughly and permanently insulated from the ceiling.

Those of our readers who are familiar with wiring and with combination fixtures and insulating joints will appreciate the object of this rule and the need of some such regulations. Those who are not familiar with the details of construction will hardly get a clear idea of what is intended from reading the rule or from this brief statement. However, all will appreciate the fact that one of the greatest danger points in any system is where gas and electricity, wires and a grounded pipe, wiremen and gas fitters all come together. The rule is intended to accomplish the following essential things: First, to keep the pipe of the fixture insulated from the grounded gas pipes; second, to keep the wires leading to the fixture away from the grounded gas pipe; third, to keep the insulated fixture from coming into contact with a grounded gas pipe or grounded ceiling, through the ornamental canopy which is used as a trim and to hide the joints in the pipe and wires.

In section 28, "Arc Lights on Low Potential Circuits," Rule "a," requiring No. 12 B. & S. wire for branch conductors, is omitted, the size of the wire being left to the table of "carrying capacities." If proper fuses are used to protect the wires, no such rule is needed. Still, it was a pretty good rule not to use a wire smaller than No. 12 B. & S. for a pair of low ampere lamps connected in series. Most lamps now on the market take an abnormal current on starting; and the defective operation of one lamp tends to increase the current in the circuit, so that it is good practice to put in a wire in a tap circuit of this kind which is large enough to carry about twice the normal current of the lamp.

In section 31, "Flexible Cord," Rule "a" is revised to read:

31. FLEXIBLE CORD:—*a*. Must be made of two-stranded conductors, each having a carrying capacity equivalent to not less than a No. 16 B. & S. wire, and each covered by an *approved* insulation, and protected by a slow-burning, tough, braided outer covering. Insulation for *pendants* under this rule must be moisture and flame-proof. Insulation for *fixture* work must be waterproof, durable and not easily abraided. Insulation for cords used for all other purposes, including portable lamps and motors, must be solid, at least $\frac{1}{32}$ of an inch in thickness, and must show an insulation resistance between conductors and between either conductor and the ground of at least one megohm per mile, after one week's immersion in water at 70 degrees Fahrenheit, with a current of 550 volts, and after three minutes' electrification.

This requires that a flexible cord shall have an insulation which is practically as good as that of *any other* conductor. This is only reasonable as, of all parts of a circuit, flexible cords are subjected to the worst conditions and treatment, and they are often located in places where a little flash would cause a fire. The cord question is still a problem, and it is well to know what kind and *what makes* of cord the underwriters approve.

Section 32, "Decorative Lamps," is changed to read:

32. DECORATIVE SERIES LAMPS:—Incandescent lamps run in series circuits shall not be used for decorative purposes inside of buildings, except by special permission in writing from the underwriters having jurisdiction.

This change seems only fair, as the only commercial "decorative" lamps have to be run in series on ordinary circuits, and there are many places where they are wanted and where they can be used with safety.

Class D, Alternating System.—Section 34, now reads:

34. IN THOSE CASES WHERE IT MAY NOT BE POSSIBLE TO EXCLUDE THE CONVERTERS AND PRIMARY WIRES ENTIRELY FROM THE BUILDING, THE FOLLOWING PRECAUTIONS MUST BE STRICTLY OBSERVED:—Converters must be located at a point as near as possible to that at which the primary wires enter the building, and must be placed in an inclosure constructed of or lined with fire-resisting material; the inclosure to be used only for this purpose, and to be kept securely locked, and access to the same allowed only to responsible persons. They must be effectually insulated from the ground and the enclosure in which they are placed must be practically air-tight, except that it shall be thoroughly ventilated to the out-door air, if possible, through a chimney or flue. There should be at least six inches air space on all sides of the converter.

This section might be changed *again* without hurting it. The building of a thoroughly ventilated and yet air-tight room is a problem that is a little out of the ordinary for an every day electrical constructor. It might be made air tight, too, as regards the building, and ventilated into the outer air by using two flues and a ventilating fan to create a draft, but *plans* should accompany such a specification as the one in the code. Again, it is considered by many experienced men that the grounding of transformer cases in basements, is good practice. Any one standing on a basement floor is pretty sure to be electrically connected to the earth and the converter case had better be in the same condition, unless it is in a converter room which is *always kept locked* and the key in the possession of an experienced and careful man. Otherwise there is liable to be a loss to a *life* insurance company. The rule is all right in one point, *i. e.*, it recognizes the fact that *any* restrictions are justified that may be necessary to secure safety. When converters are placed in buildings they should be made safe regardless of expense. The only question is as to the *surest* way of doing it.

Class E, Electrical Railways.—This part of the code is unchanged except in section 42, "Car Houses." This section now reads as follows:

42. CAR HOUSES:—*a.* Must have the trolley wires properly supported on insulating hangers. *b.* Must have the trolley hangers placed at such a distance apart that in case of a break in the trolley wire, contact cannot be made with the floor. *c.* Must have cut-out switch located at a proper place outside the building, so that all trolley circuits in the building can be cut out at one point, and the line circuit breakers must be installed, so that when this cut-out switch is open the trolley wire will be dead at all points within 100 feet of the building. The current must be cut out of the building whenever the same is not in use, or the road not in operation. *d.* Must have all lamps and stationary motors installed in such a way that one main switch can control the whole of each installation (lighting or power), independently of main feeder switch. No portable incandescent lamps or twin wire allowed, except that portable incandescent lamps may be used in the pits; connections to be made by two approved rubber-covered flexible wires, properly protected against mechanical injury; the circuit to be controlled by a switch placed outside the pit. *e.* Must have all wiring and apparatus installed in accordance with rules under Class B. *f.* Must not have any system of feeder distribution centering in the building. *g.* Must have the rails bonded at each joint with not less than No. 2 B. &

S. annealed copper wire; also a supplementary wire to be run for each track. *h*. Must not have cars left with trolley in electrical connection with the trolley wire.

The use of a street railway current of 500 volts pressure is not allowed in any building except street railway power houses and car barns, and in these last it is practically a necessity. The code permits such usage, but requires almost every precaution that can be suggested. Rule "e" requires that the wires be run in the same manner as for high potential systems. Rule "f" prohibits the placing of conductors in the car barn for *any* purpose *except the necessary service of the barn.* Rule "a" requires the use of the same insulation that is used on the trolley wires out of doors. Rule "b" is to prevent the possibility of a flash in case the trolley wire should break and come into contact with the rails, which are electrically connected to the track outside the barn, as per Rule "g," and therefore of opposite polarity. Rule "h" prevents the possibility of the cars taking fire in the car barns. Rules "c" and "d" insist on such an installation that any circuit not in proper condition or not needed can be instantly disconnected, and that when electricity is not needed in the barn, no current can pass into it from the trolley wires or feeders. This last requirement is very essential to protect the barn against lightning. For those who are not familiar with car barns we will say that the "pits" referred to are located between the rails of each track inside the barn so that a man can get into a "pit," and thus have room under a car to examine and repair the motors and running gear.

Naturally a man wants a light for such work, and if he cannot have an incandescent light he will take a torch. In spite of the apparent difficulty in securing safety in car barns, the use of electricity, with such construction as is required by the above rule, is quite safe, and infinitely safer than lighting the barn with gas, oil, torches, etc. The fact that the lights, motors, etc., are used only by men who know how electricity acts at 500 volts pressure on a grounded circuit, reduces the danger to life and property to a minimum, but the use of such a current in a car barn should not be taken as an argument for allowing its use promiscuously.

Class F, Electrical Heaters.—This is the heading of a new class in the revised code; the text is as follows:

44. CLASS F. ELECTRICAL HEATER:—*a*. If stationary, must be placed in a safe situation, isolated from inflammable materials and treated as stoves. *b*. Must have double-pole *indicating* switches and double-pole cut-outs arranged as required for electric light or power of same potential and current. *c*. Must have the attachments of feed wires to the heaters in plain sight, easily accessible and protected from interference, accidental or otherwise. *d*. The flexible conductors for portable apparatus, such as irons, etc., must have an insulation that will not be injured by heat, such as asbestos, which must be protected from mechanical injury by an outer substantial braided covering, and so arranged that mechanical strain will not be borne by the electrical connections.

Sections "a," "b" and "c" are self-explanatory. Section "d" is necessitated by the fact that the appliances mentioned are used in a careless manner, being operated for the most part by people who do not appreciate the damage that may be caused by improper usage.

Miscellaneous.—In Rule 46, section "a" every circuit is required to have an insulation of at least 100,000 ohms instead of 25,000 ohms, as in the preceding edition. This standard is surely low enough, and to make it any lower is absurd, when 4,000,000 ohms is required for an installation of 10 amperes, which is a greater current than is carried by the ordinary branch circuit. Two circuits with an insulation resistance of 100,000 ohms each would bring the insulation of an 800-light plant way below the 80,000 ohms required. In most plants an insulation resistance of a megohm (1,000,000) ohms per circuit is low enough to allow, but as a universal rule the 100,000 ohm limit is all right when taken in connection with the table which follows in the code.

Section "e" of the old code is made section "f" in the revised code, and the following section is added:

e. The metallic sheathes to cables must be permanently and effectually connected to earth.

The utility of this rule in all cases may be questioned, but it is probably based upon results obtained in practice. These miscellaneous rules will probably be revised many times; but as they now stand they are far ahead of practice. At the present time each man protects his particular system of conductors as best he can. The leading electric light companies are in advance of the code in their practice, and the ordinary small *unmanaged* company has its system protected by guesswork and Providence.

Wires.—The code of January 1st, 1896, publishes a new list of wires, as follows:

WIRES:—The following is a list of wires which have been tested and been found to comply with the standard for *approved* wires, required for *all* high potential work (300 volts or over) and for service wires, all classes of concealed wiring and wiring exposed to dampness in low potential work:—

Name of Wire.	*Manufacturer.*
Americanite..................	American Electrical Works.
Bishop	Bishop Gutta Percha Co.
Clark	Eastern Electric Cable Co.
Climax	Simplex Electric Co.
Simplex (caoutchouc)	Simplex Electric Co.
Crescent	John A. Roebling's Sons Co.
Crown.......................	Washburn & Moen.
Globe	Washburn & Moen.
Salamander	Washburn & Moen.
Crefeld	Crefeld Electrical Works.
Grimshaw (White core)	N. Y. Insulated Wire Co.
Raven core	N. Y. Insulated Wire Co.
Requa (White core).........	Safety Insulated Wire & Cable Co.
Safety (Black core)	Safety Insulated Wire & Cable Co.
Habirshaw (White core)	Ind. Rubber & Gutta Percha Ins. Co.
Habirshaw (Blue core)......	Ind. Rubber & Gutta Percha Ins. Co.
Habirshaw (Red core)	Ind. Rubber & Gutta Percha Ins. Co.
Paranite	Indiana Rubber & Insulated Wire Co
Liberty.....................	Atlas Covering Works.
Kerite	W. R. Brixey.
Okonite.....................	Okonite Co.
Paracore	Nat. India Rubber Co.
N. I. R.....................	Nat. India Rubber Co.
U. S........................	General Electric Co.
Columbia	C. S. Knowles.

NOTE.—The results of recent tests on these and other wires can be seen at inspection office.

Whatever we had to say about the old list applies to this list as well. Rubber covered wire has steadily become cheaper; we *hope* it has at the same time become *better*, but we fear it has not. One thing is certain, for high potentials and damp places the best is none too good and the best is certainly the cheapest.

Any portion of the code to which we have not referred in this and the next preceding chapter remains unchanged. In this book we have tried to explain the meaning and object of the code, and we will close with a brief statement concerning its *limitation*. The object of the code is to secure *safety*, nothing else. It does not indicate how to install a plant so as to get *reliable service*, or even and uniform lighting. The code insists upon the use of the best methods and materials that can be insisted upon without making the use of electricity prohibitive or working a hardship upon the user. The code is *not* a *specification* of how to install an electric plant, and it should not be used as a *substitute* for one. It simply tells what must, and what must not be done, in order to secure safety. When carefully studied, it indicates the methods and means to be adopted to secure *safety* in *all* cases. As the art advances, the application of electricity will become more safe and the requirements of the code will become more rigid. It is susceptible of many improvements, but as it exists today, it is far, far ahead of general practice. Only in a few large cities is the standard of the code even approximately maintained; and it should be the aim of every electrical engineer and every man interested in fire insurance to try to raise the practice to the standard of the code. Although we have taken up more space than we originally anticipated, we feel that, so far from exhausting the subject, we have only been able to cover it in a very superficial manner; but we trust that we have at least shown that the code is worthy of careful study by every one interested in the application of electricity, and hope we have aided our readers in obtaining an understanding of its principles.

APPENDIX.

TABLES AND CURVES.

The accompanying table and curves show the relations existing between the sectional area and the "maximum safe carrying capacity" of insulated copper wires.

Explanation of Table.—Columns I., IV. and VI. are the same as given in the Code. Column II. gives the diameter of the wires in inches, and column III. gives the corresponding circular mils. In ordinary computations and comparisons, circular mils are used instead of areas. The circular mils of a wire are proportional to its sectional area. The square mils may be obtained from the circular mils by multiplying by .7854, and the sectional area in square inches may be obtained by dividing the square mils by 1,000,000. Column V. is obtained by division from columns III. and IV.; and column VII. is obtained in the same way from columns III. and VI.

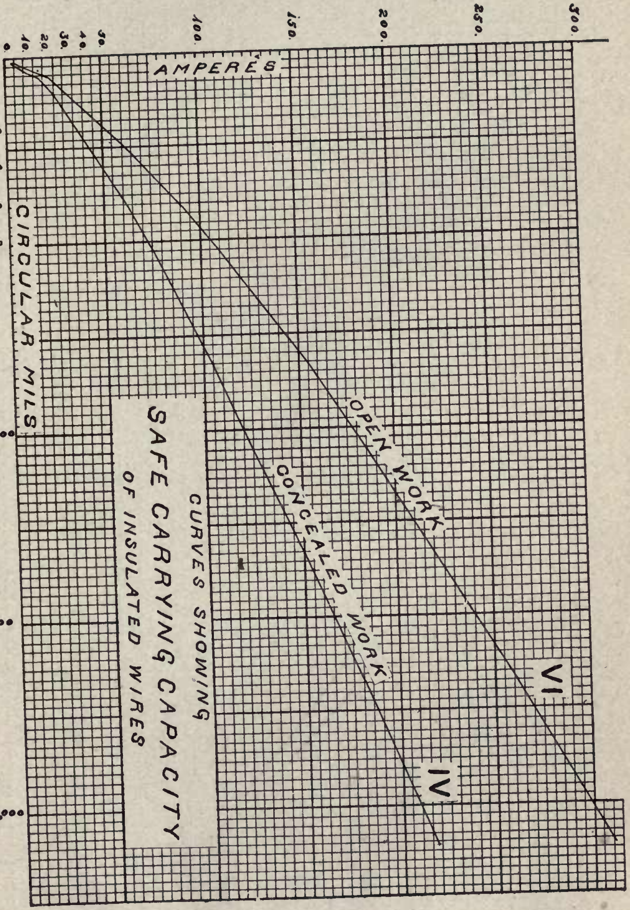
Explanation of Curves:—Curves IV., V., VI. and VII. represent graphically the columns correspondingly numbered in the table. *To find the carrying capacity of any wire from the curves.*—On the base line marked circular mils, find the point corresponding to the circular mils of the wire. Follow up the vertical line through this point until it intersects curve IV. or VI., according as the wire is to be concealed or open. From this intersection point follow horizontal line to the vertical line marked "Amperes." The desired number in amperes can then be read on this vertical line. To find the corresponding circular mils per ampere, follow the same method with curves V. or VII.

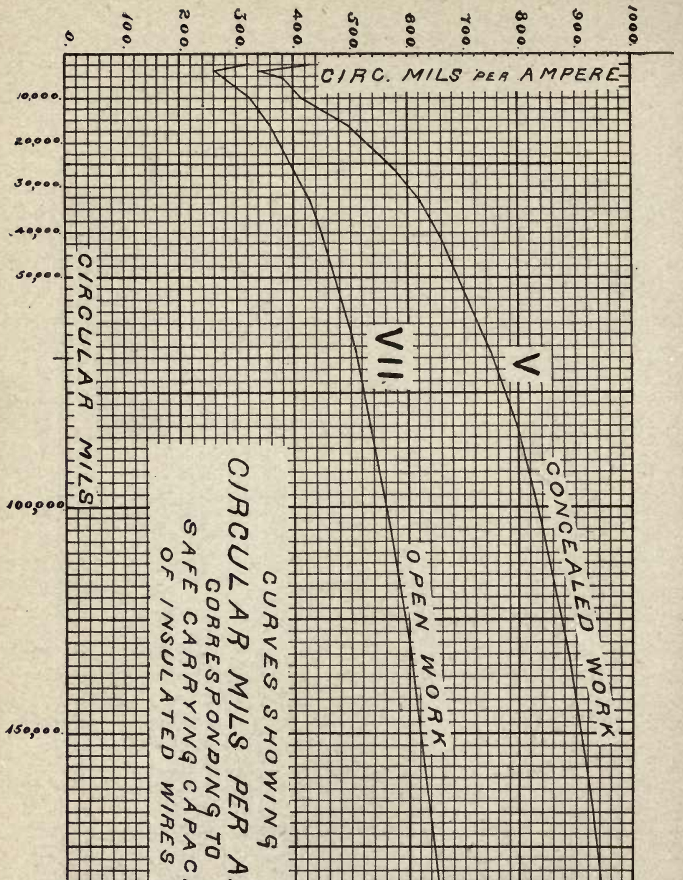
Table Showing Relation Between Size and Safe Carrying Capacity of Insulated Copper Wires.

Size B. & S. Gauge.	Diameter of Wire in Inches.	Sectional Area in Circular Mils.	Concealed Work.		Open Work.	
			Safe Carrying Capacity in Amperes.	Circular Mils per Ampere.	Safe Carrying Capacity in Amperes.	Circular Mils per Ampere.
I.	II.	III.	IV.	V.	VI.	VII.
0000	.46	211600	218	971	312	679
000	.4096	167800	181	927	262	640
00	.3648	133100	150	887	220	605
0	.325	105500	125	844	185	570
1	.3893	83600	105	797	156	536
2	.2576	66370	88	754	131	507
3	.2294	52630	75	702	110	478
4	.2043	41740	63	662	92	453
5	.1819	33100	53	625	77	430
6	.1620	26250	45	583	65	404
8	.1285	16510	33	500	46	359
10	.1019	10380	25	415	32	325
12	.0808	6530	17	384	23	283
14	.0641	4107	12	342	16	257
16	.0508	2583	6	431	8	323
18	.0403	1624	3	541	5	325

Note.—The "circular mils" of a wire is the square of the diameter expressed in thousandths of an inch.

If D = diameter of wire in inches (column II.), then circular mils = $D^2 \times 1{,}000{,}000$ (column III.).


AMPERES
0.
10.
20.
30.
40.
50.
100.
150.
200.
250.
300.
CIRCULAR MILS
10,000
20,000
30,000
40,000
50,000
100,000
150,000
200,000
OPEN WORK
CONCEALED WORK
VI
IV
CURVES SHOWING
SAFE CARRYING CAPACITY
OF INSULATED WIRES


CURVES SHOWING
CIRCULAR MILS PER AMPERE
CORRESPONDING TO
SAFE CARRYING CAPACITY
OF INSULATED WIRES
CIRC. MILS PER AMPERE
CIRCULAR MILS
CONCEALED WORK
OPEN WORK
V
VII
0.
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
10,000.
20,000.
30,000.
40,000.
50,000.
100,000.
150,000.
200,000.

APPENDIX.

RULES AND REQUIREMENTS

OF THE

National Board of Fire Underwriters

For the Installation of Wiring and Apparatus for Electric Light, Heat and Power as Recommended by the Underwriters' National Electric Association.

Edition of January 1, 1896.

GENERAL SUGGESTIONS.

In all electric work conductors, however well insulated, should always be treated as bare, to the end that under no conditions, existing or likely to exist, can a grounding or short circuit occur, and so that all leakage from conductor to conductor, or between conductor and ground, may be reduced to the minimum.

In all wiring special attention must be paid to the mechanical execution of the work. Careful and neat running, connecting, soldering, taping of conductors and securing and attaching of fittings, are specially conducive to security and efficiency, and will be strongly insisted on.

In laying out an installation the work should, if possible, be started from a center of distribution, and the switches and cut-outs, controlling and connected with the several branches, be grouped together in a safe and easily accessible place, where they can be readily got at for attention or repairs. The load should be divided as evenly as possible among the branches and all complicated and unnecessary wiring avoided.

The use of wire-ways for rendering concealed wiring permanently accessible is most heartily endorsed and recommended;

and this method of accessible concealed construction is advised for general use.

Architects are urged, when drawing plans and specifications, to make provision for the channeling and pocketing of buildings for electric light or power wires, and in specifications for electric gas lighting to require a two-wire circuit, whether the building is to be wired for electric lighting or not, so that no part of the gas fixtures or gas piping be allowed to be used for the gas-lighting circuit.

CLASS A, CENTRAL STATIONS.

FOR LIGHT OR POWER

(These rules also apply to dynamo rooms in isolated plants connected with or detached from buildings used for other purposes; also to all varieties of apparatus therein of both high and low potential).

1. GENERATORS:—

a. Must be located in a dry place.

b. Must be insulated on floors or base frames, which must be kept filled to prevent absorption of moisture, and also kept clean and dry. Where frame insulation is impossible, the Inspector may, in writing, permit its omission, in which case the frame must be permanently and effectively grounded.

c. Must never be placed in a room where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases or flyings of combustible material.

d. Must each be provided with a waterproof covering.

2. CARE AND ATTENDANCE:—

A competent man must be kept on duty in the room where generators are operating.

Oily waste must be kept in *approved* metal cans and removed daily.

Approved waste cans shall be made of metal, with legs raising can three inches from the floor, and with self-closing covers.

3. CONDUCTORS:—

From generators, switchboards, rheostats or other instruments, and thence to outside lines, conductors

a. Must be in plain sight or readily accessible.

b. Must be wholly on non-combustible insulators, such as glass or porcelain.

c. Must be separated from contact with floors, partitions or walls, through which they may pass, by non-combustible insulating tubes, such as glass or porcelain.

d. Must be kept rigidly so far apart that they cannot come in contact.

e. Must be covered with non-inflammable insulating material sufficient to prevent accidental contact, except that "bus bars" may be made of bare metal.

f. Must have ample carrying capacity to prevent heating. (See Table of Capacity of Wires.)

4. SWITCHBOARDS:—

a. Must be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material.

Special attention is called to the fact that switchboards should not be built down to the floor, nor up to the ceiling, but a space of at least eighteen inches, or two feet, should be left between the floor and the board, and between the ceiling and the board, in order to prevent fire from communicating from the switchboard to the floor or ceiling, and also to prevent the forming of a partially concealed space very liable to be used for storage or rubbish and oily waste.

b. Must be accessible from all sides when the connections are on the back; or may be placed against a brick or stone wall when the wiring is entirely on the face.

c. Must be kept free from moisture.

d. Must be made of non-combustible material, or of hardwood in skeleton form, filled to prevent absorption of moisture.

e. Bus bars must be equipped in accordance with Rule 3 for placing conductors.

5. RESISTANCE BOXES AND EQUALIZERS:—

a. Must be equipped with metal, or other non-combustible frames.

The word "frame" in this section relates to the entire case and surroundings of the rheostat, and not alone to the upholding supports.

b. Must be placed on the switchboard, or, if not thereon, at a distance of a foot from combustible material, or separated therefrom by a non-inflammable, non-absorptive, insulating material.

6. LIGHTNING ARRESTERS:—

a. Must be attached to each side of every overhead circuit connected with the station.

b. Must be mounted on non-combustible bases in plain sight on the switchboard, or in any equally accessible place, away from combustible material.

c. Must be connected with at least two "earths" by separate metallic strips or wires having a conductivity not less than that of a No. 6 B. & S. wire. These strips or wires must be run as nearly as possible in a straight line from the arresters to the earth connection.

d. Must be so constructed as not to maintain an arc after the discharge has passed, and must have no moving parts.

It is recommended to all electric light and power companies that arresters be connected at intervals over systems in such numbers and so located as to prevent ordinary discharges entering, over the wires, buildings connected to the lines.

7. TESTING:—

a. All series and alternating circuits must be tested every two hours while in operation to discover any leakage to earth, abnormal in view of the potential and method of operation.

b. All multiple arc low-potential systems (300 volts or less) must be provided with an indicating or detecting device, readily attachable, to afford easy means of testing.

c. Data obtained from all tests must be preserved for examination by insurance inspectors.

These rules on testing to be applied at such places as may be designated by the association having jurisdiction.

8. MOTORS:—

a. Must be wired under the same precautions as with a current of the same volume and potential for lighting. The motor and resistance box must be protected by a double-pole cut-out and controlled by a double-pole switch, said switch plainly indicating whether "on" or "off," except in cases where one-quarter horse-power or less is used on low-tension circuits a single-pole switch will be accepted.

b. Must be thoroughly insulated, mounted on filled, dry wood, be raised at least eight inches above the surrounding floor, be provided with pans to prevent oil from soaking into the floor, and must be kept clean.

c. Must be covered with a waterproof cover when not in use, and, if deemed necessary by the inspector, be inclosed in an *approved* case.

From the nature of the question, the decision as to what is an *approved* case must be left to the inspector to determine in each instance.

d. Must be, when combined with ceiling fans, hung from insulated hooks, or else there shall be an insulator interposed between the motor and its support.

9. RESISTANCE BOXES:—

a. Must be equipped with metal or other non-combustible frames.

The word "frame" in this section relates to the entire case and surroundings of the rheostat, and not alone to the upholding supports.

b. Must be placed on the switchboard, or at a distance of a foot from combustible material. or separated therefrom by a non-inflammable, non-absorptive insulating material.

CLASS B. HIGH POTENTIAL SYSTEMS

(OVER 300 VOLTS)

(Any circuit attached to any machine, or combination of machines, which develops over 300 volts difference of potential between any two wires, shall be considered as a high potential circuit and coming under that class, unless an approved transforming device is used which cuts the difference of potential down to less than 300 volts.)

10. OUTSIDE CONDUCTORS:—

All outside, overhead conductors (including services)

a. Must have an *approved* insulating covering, and be firmly secured to properly insulated and substantially built supports, all tie wires having an insulation equal to that of the conductors they confine.

Insulation that will be *approved* for *service wires* must be solid, at least $\frac{3}{64}$ of an inch in thickness and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water, with a current of 550 volts, and after three minutes' electrification.

A wire with an insulating covering that will not support combustion, will resist abrasion, is at least $\frac{1}{16}$ of an inch in thickness, and thoroughly impregnated with a moisture repellant, will be *approved* for outside overhead conductors, except service wires.

b. Must be so placed that moisture cannot form a cross connection between them, not less than a foot apart, and not in contact with any substance other than their insulating supports.

c. Must be at least seven feet above the highest point of flat roofs, and at least one foot above the ridge of pitched roofs over which they pass or to which they are attached.

d. Must be protected by *dead insulated guard irons* or *wires* from possibility of contact with other conducting wires or substances to which current may leak. Special precautions of this kind must be taken where sharp angles occur, or where any wires might possibly come in contact with electric light or power wires.

e. Must be provided with petticoat insulators of glass or porcelain. Porcelain knobs or cleats and rubber hooks will not be approved.

f. Must be so spliced or jointed as to be both mechanically and electrically secure without solder. The joints must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

All joints must be soldered, even if made with the McIntyre or any other patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

g. Telegraph, telephone and similar wires must not be placed on the same cross-arm with electric light or power wires.

11. SERVICE BLOCKS:—

Must be covered over their entire surface with at least two coats of waterproof paint.

12. ALL INTERIOR CONDUCTORS:—

a. Must be covered where they enter buildings from outside terminal insulators to and through the walls with extra waterproof insulation and must have drip loops outside. The hole through which the conductor passes must be bushed with waterproof and non-combustible insulating tube, slanting upwards toward the inside. The tube must be sealed with tape, thoroughly painted, and securing the tube to the wire.

b. Must be arranged to enter and leave the building through a double-contact service switch, which will effectually close the main circuit and disconnect the interior wires when it is turned "off." The switch must be so constructed that it shall be automatic in its action, not stopping between points when started, and prevent an arc between the points under all circumstances; it must indicate on inspection whether the current be "on" or "off," and be mounted in a non-combustible case, and kept free from moisture, and easy of access to police or firemen. So-called "snap switches" shall not be used on a high potential system.

c. Must be always in plain sight, and never encased, except when *required* by the Inspector.

d. Must have an *approved* insulating covering.

Insulation that will be *approved* for interior conductors must be solid, at least $\frac{3}{64}$ of an inch in thickness and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water, with a current of 550 volts, and after three minutes' electrification.

e. Must be supported on glass or porcelain insulators, and kept rigidly at least eight inches from each other, except within the structure of lamps or on hanger-boards, cut-out boxes, or the like, where less distance is necessary.

f. Must be separated from contact with walls, floors, timbers or partitions through which they may pass by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain.

g. Must be so spliced or joined as to be both mechanically and electrically secure without solder. They must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

All joints must be soldered, even if made with the McIntyre or any other patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

h. Must be protected from mechanical injury, when necessary on side walls, by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top, and extending not less than five feet from the floor. Where crossing exposed floor timbers in cellars or rooms, the conductors must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness.

LAMPS AND OTHER DEVICES.

13. ARC LAMPS—In every case:—

a. Must be carefully isolated from inflammable material.

b. Must be provided at all times with a glass globe surrounding the arc, securely fastened upon a closed base. No broken or cracked globes to be used.

c. Must be provided with an *approved* hand-switch, also an automatic switch that will shunt the current around the carbons should they fail to feed properly.

The hand-switch to be *approved*, if placed anywhere except on the lamp itself, must comply with requirements for switches on hanger-boards as laid down in Section *g* of Rule 13.

d. Must be provided with reliable stops to prevent carbons from falling out in case the clamps become loose.

e. Must be carefully insulated from the circuit in all their exposed parts.

f. Must be provided with a wire netting (having a mesh not exceeding one and one-quarter inches) around the globe, and an *approved* spark arrester above, to prevent escape of sparks, melted copper or carbon, where readily inflammable material is in the vicinity of the lamps. It is recommended that plain carbons, not copper-plated, be used for lamps in such places.

An *approved* spark arrester is one which will so close the upper orifice of the globe that it will be impossible for any sparks thrown off by the carbons to escape.

Arc lamps, when used in places where they are exposed to flyings of easily inflammable material, should have the carbons enclosed completely in a globe in such manner as to avoid the necessity for spark arresters. For the present, spark arresters will not be required on so-called "inverted arc" lamps.

g. Hanger-boards must be so constructed that all wires and current-carrying devices thereon shall be exposed to view and thoroughly insulated by being mounted on a non-combustible, non-absorptive, insulating substance. All switches attached to the same must be so constructed that they shall be automatic in their action, cutting off both poles to the lamp, not stopping between points when started, and preventing an arc between points under all circumstances.

h. Where hanger-boards are not used, lamps to be hung from insulated supports other than their conductors.

14. INCANDESCENT LAMPS IN SERIES CIRCUITS HAVING A MAXIMUM POTENTIAL OF 300 VOLTS OR OVER:—

a. Must have the conductors installed as provided in Rule 12, and each series lamp must be provided with an automatic cut-out.

b. Must have each lamp suspended from a hanger-board by means of rigid tubes.

c. No electro-magnetic device for switches and no system of multiple-series or series-multiple lighting will be approved.

d. Under no circumstances can series lamps be attached to gas fixtures.

CLASS C, LOW POTENTIAL SYSTEMS.

(300 VOLTS OR LESS.)

OUTSIDE CONDUCTORS.

15. OUTSIDE OVERHEAD CONDUCTORS:—

a. Must be erected in accordance with the rules for high potential conductors.

b. Must be separated not less than twelve inches, and be provided with an *approved* fusible cut-out, that will cut off the entire current as near as possible to the entrance to the building and inside the walls.

An *approved* fusible cut-out must comply with the sections of Rules 23 and 24, describing fuses and cut-outs. The cut-out required by this section must be placed so as to protect the switch required by Rule 17.

16. UNDERGROUND CONDUCTORS:—

a. Must be protected, when brought into a building, against moisture and mechanical injury, and all combustible material must be kept removed from the immediate vicinity.

b. Must have a switch and a cut-out for each wire between the underground conductors and the interior wiring when the two parts of the wiring are connected.

These switches and fuses must be placed as near as possible to the end of the underground conduit, and connected therewith by specially insulated conductors, kept apart by not less than two and one-half inches.

The cut-out required by this section must be placed so as to protect the switch.

c. Must not be so arranged as to shunt the current through a building around any catch box.

INSIDE WIRING. GENERAL RULES.

17. At the entrance of every building there shall be an *approved* switch placed in the service conductors by which the current may be entirely cut off.

The switch required by this rule, to be *approved*, must be of such construction that each wire entering the building will be disconnected when the switch is open, must plainly indicate whether the current is "on" or "off," and must comply with sections *a*, *c*, *d* and *e* of Rule 26, relating to switches.

18. CONDUCTORS:—

a. Must have an *approved* insulating covering, and must not be of sizes smaller than No. 14 B. & S., No. 16 B. W. G. or No. 4 E. S. G., except as allowed under Rule 27 (*d*) and 31 (*a*).

In so-called "concealed" wiring, moulding and conduit work, *and* in places liable to be exposed to dampness, the insulating covering of the wire, to be *approved*, must be solid, at least $\frac{3}{64}$ of an inch in thickness, and covered with a substantial braid. It must not readily carry fire; must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water, with a current of 550 volts, and after three minutes' electrification.

For work which is *entirely* exposed to view throughout the whole interior circuits, and not liable to be exposed to dampness, a wire with an insulation covering that will not support combustion, will resist abrasion, is at least $\frac{1}{16}$ of an inch in thickness and thoroughly impregnated wfth a moisture repellant, will be *approved*.

b. Must be protected when passing through floors, walls, partitions, timbers, etc., by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain.

c. Must be kept free from contact with gas, water or other metallic piping, or any other conductors or conducting material which they may cross, by some continuous and firmly fixed non-conductor, creating a separation of at least one inch. Deviations from this rule may sometimes be allowed by special permission.

d. Must be so placed in wet places that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run *over* all pipes upon which moisture is liable to gather, or which by leaking might cause trouble on a circuit.

e. Must be so spliced or joined as to be both mechanically and electrically secure without solder. They must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

All joints must be soldered, even if made with the McIntyre or any other patent splicing device. This ruling applies to joints and splices in all classes of wiring covered by these rules.

f. Must be protected from mechanical injury, when necessary on side walls, by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top, and extending not less than five feet from the floor, or by an iron-armored or metal-sheathed insulating conduit sufficiently strong to withstand the strain it will be subjected to, the inner insulating tubing to extend one-half inch beyond the ends of the metal tube, which must extend not less than five feet from the floor. Where crossing exposed floor timbers in cellars or rooms, the conductors must be attached by their insulating supports to the under side of a wooden strip not less than one-half inch in thickness and not less than three inches in width.

SPECIAL RULES.

19. WIRING NOT INCASED IN MOULDING OR APPROVED CONDUIT:—

a. Must be supported wholly on non-combustible insulators, constructed so as to prevent the insulating coverings of the wire from coming in contact with other substances than the insulating supports.

b. Must be so arranged that wires of opposite polarity, with a difference of potential of 150 volts or less, will be kept apart at least two and one-half inches.

c. Must have the above distance increased proportionately where a higher voltage is used.

d. Must not be laid in plaster, cement or similar finish.

e. Must never be fastened with staples.

IN UNFINISHED LOFTS, BETWEEN FLOOR AND CEILINGS, IN PARTITIONS AND OTHER CONCEALED PLACES.

f. Must have at least one inch clear air space surrounding them.

g. Must be at least ten inches apart when possible, and should be run singly on separate timbers or studding.

h. Wires run as above immediately under roofs, in proximity to water tanks or pipes, will be considered as exposed to moisture.

i. When from the nature of the case it is impossible to place concealed wire on non-combustible insulating supports of glass or porcelain, the wires may be fished on the loop system, if encased throughout in *approved* continuous flexible tubing or conduit.

American Circular Loom Tubing is approved for use under this rule.

j. Wires must not be fished for any great distance, and only in places where the Inspector can satisfy himself that the above rules have been complied with.

k. Twin wires must never be employed in this class of concealed work.

20. MOULDINGS:—

a. Must never be used in concealed work or in damp places.

b. Must have, both outside and inside, at least two coats of waterproof paint, or be impregnated with a moisture repellant.

c. Must be made of two pieces, a backing and capping, so constructed as to thoroughly encase the wire and provide a one-half inch tongue between conductors and a solid backing which, under grooves, shall not be less than three-eighths of an inch in thickness and must afford suitable protection from abrasion.

It is recommended that only hardwood moulding be used.

21. SPECIAL WIRING:—

In breweries, packing-houses, stables, dye-houses, paper and pulp mills, or other buildings specially liable to moisture or acid, or other fumes liable to injure the wires or insulation, except where used for pendants, conductors—

a. Must be separated at least six inches, and should have no joints or splices.

b. Must be provided with an *approved* insulating covering.

The insulating covering of the wire to be *approved* under this section must be solid, at least $\frac{3}{64}$ of an inch in thickness and covered with a substantial braid. It must not readily carry fire, must show an insulating resistance of one megohm per mile after two weeks' submersion in water at 70 degrees Fahrenheit, and three days' submersion in lime water, with a current of 550 volts, after three minutes' electrification, and must *also* withstand a satisfactory test against such chemical compounds or mixtures as it will be liable to be subjected to in the risk under consideration.

c. Must be carefully put up.

d. Must be supported by glass or porcelain insulators. No switches, key-sockets or fusible cut-outs will be allowed where exposed to inflammable gases or dust, or to flyings of combustible material. In damp places switches and cut-out blocks must be mounted on porcelain knobs.

e. Must be protected when passing through floors, walls, partitions, timbers, etc., by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain.

22. INTERIOR CONDUITS*:—

The American Circular Loom Company Tube, the *brass-sheathed* and the *iron-armored* tubes made by the Interior Conduit and Insulation Company, the *iron-armored* tube made by the Builders' Insulating Tube Company, of Lynn, Mass., the *iron-armored* tube made by the Clifton Mfg. Co., of Boston, and the Vulca Tube, are approved for the class of work called for in this rule.

a. Must be continuous from one junction box to another, or to fixtures, and must be of material that will resist the fusion of the wire or wires they contain without igniting the conduit.

*The object of a tube or conduit is to facilitate the insertion or extraction of the conductors, to protect them from mechanical injury, and, as far as possible, from moisture. Tubes or conduits are to be considered merely as raceways, and are not to be relied on for insulation between wire and wire, or between the wire and the ground.

b. Must not be of such material or construction that the insulation of the conductor will ultimately be injured or destroyed by the elements of the composition.

c. Must be first installed as a complete conduit system, without the conductors, which must not be drawn in until all mechanical work on the building has been, as far as possible, completed.

d. Must not be so placed as to be subject to mechanical injury by saws, chisels or nails.

e. Must not be supplied with a twin conductor or two separate conductors in a single tube, except in an *approved* iron or steel-armored conduit.

The use of approved wires of opposite polarity, either separate or twin conductor, in a straight conduit installation, is allowed in *approved* iron-armored or steel-armored conduits, but not in any of the other approved conduits.

Iron or steel-armored conduit to be approved must fulfill the following specifications:

1. Must not be seriously affected externally by burning out a wire inside the tube when the iron pipe is connected to one side of the circuit.

2. When bent with a sag of one foot in the middle of a ten-foot length, and filled with water, must have an insulation resistance between the water and the iron pipe of one megohm after three days, temperature being 21 degrees Centigrade (70 degrees Fahrenheit).

3. The insulating material removed from the tube must not absorb more than ten per cent., by weight, of water after one weeks' immersion.

4. The insulating material must not soften at a temperature below 70 degrees Centigrade (158 degrees Fahrenheit), and must leave the water in which it is boiled practically neutral.

5. The insulating material must not become mechanically weak after three days' immersion in water.

f. Must have all ends closed with good adhesive material, either at junction boxes or elsewhere, whether such ends are concealed or exposed. Joints must be made air-tight and moisture-proof.

g. Conduits must extend at least one inch beyond the finished surface of walls or ceilings until the mortar or other similar material be entirely dry, when the projection may be reduced to half an inch.

23. Double-Pole Safety Cut-outs:—

a. Must be in plain sight or inclosed in an *approved* box, and readily accessible. They must not be placed in the canopies or shells of fixtures.

To be *approved* boxes must be constructed, and cut-outs arranged, whether in a box or not, so as to obviate any danger of the melted fuse metal coming in contact with any substance which might be ignited thereby.

b. Must be placed at every point where a change is made in the size of the wire (unless the cut-out in the larger wire will protect the smaller).

c. Must be supported on bases of non-combustible, insulating, moisture-proof material.

d. Must be supplied with a plug (or other device for inclosing the fusible strip or wire) made of non-combustible and moisture-proof material, and so constructed that an arc cannot be maintained across its terminals by the fusing of the metal.

e. Must be so placed that no set of lamps, whether grouped on one fixture or on several fixtures or pendants, requiring a current of more than six amperes, shall be ultimately dependent upon one cut-out. Special permission may be given in writing by the Inspector for departure from this rule in case of large chandeliers.

24. SAFETY FUSES:—

a. Must all be stamped or otherwise marked with the maximum number of amperes they will carry indefinitely without melting.

b. Must have fusible wires or strips (where the plug or equivalent device is not used), with contact surfaces or tips of harder metal, soldered or otherwise, having perfect electrical connection with the fusible part of the strip.

c. Must all be so proportioned to the conductors they are intended to protect that they will melt before the maximum safe-carrying capacity of the wire is exceeded.

25. TABLE OF CAPACITY OF WIRES:—

It must be clearly understood that the size of the fuse depends upon the size of the smallest conductor it protects and not upon the amount of current to be used on the circuit. Below is a table showing the safe carrying capacity of conductors of different sizes in Brown & Sharpe gauge, which must be followed in the placing of interior conductors:—

	TABLE A, CONCEALED WORK.	TABLE B, OPEN WORK.
B. & S. G.	*Amperes.*	*Amperes.*
0000	218	312
000	181	262
00	150	220
0	125	185
1	105	156
2	88	131
3	75	110
4	63	92
5	53	77
6	45	65
8	33	46
10	25	32
12	17	23
14	12	16
16	6	8
18	3	5

NOTE.—By "open work" is meant construction which admits of all parts of the surface of the insulating covering of the wire being surrounded by *free* air. The carrying capacity of 16 and 18 wire is given, but no wire smaller than 14 is to be used, except allowed under Rules 27 (*d*) and 31 (*a*).

26. SWITCHES:—

a. Must be mounted on moisture-proof and non-combustible bases, such as slate or porcelain.

b. Must be double pole when the circuits which they control supply more than six 16 candle-power lamps, or their equivalent.

c. Must have a firm and secure contact; must make and break readily, and not stop when motion has once been imparted by the handle.

d. Must have carrying capacity sufficient to prevent heating.

e. Must be placed in dry, accessible places, and be grouped as far as possible, being mounted—when practicable—upon slate or equally non-combustible back boards. Jackknife switches, whether provided with friction or spring stops, must be so placed that gravity will tend to open rather than close the switch.

27. FIXTURE WORK:—

a. In all cases where conductors are concealed within or attached to gas fixtures, the latter must be insulated from the gas-pipe system of the building by means of *approved* insulating joints placed as close as possible to the ceiling.

Insulating joints with soft rubber in their construction will not be approved. It is recommended that the gas-outlet pipe be protected above the insulating joint by a non-combustible, non-absorptive insulating tube having a flange at the lower end, where it comes in contact with the insulating joint, and that, where outlet tubes are used, they be of sufficient length to extend below the joint, and that they be so secured that they will not be pushed back when the canopy is put in place. Where iron ceilings are used care must be taken to see that the canopy is thoroughly and permanently insulated from the ceiling.

Insulating joints to be *approved* must be entirely made of material that will resist the action of illuminating gases, and will not give way or soften under the heat of an ordinary gas flame. They shall be so arranged that a deposit of moisture will not destroy the insulating effect, and shall have an insulating resistance of 250,000 ohms between the gas-pipe attachments, and be sufficiently strong to resist the strain they will be liable to in attachment.

b. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas pipes, and where shells are used, the latter must be constructed in a manner affording sufficient area to allow this requirement.

c. When fixtures are wired outside, the conductors must be so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture.

d. All conductors for fixture work must have a waterproof insulation that is durable and not easily abraded, and must not in any case be smaller than No. 18 B. & S., No. 20 B. W. G., No. 2 E. S. G.

e. All burs or fins must be removed before the conductors are drawn into a fixture.

f. The tendency to condensation within the pipes should be guarded against by sealing the upper end of the fixture.

g. No combination fixture in which the conductors are concealed in a space less than one-fourth inch between the inside pipe and the outside casing will be approved.

h. Each fixture must be tested for "contacts" between conductors and fixtures, for "short circuits," and for ground connections before the fixture is connected to its supply conductors.

i. Ceiling blocks of fixtures should be made of insulating material; if not, the wires in passing through the plate must be surrounded with hard-rubber tubing.

28. Arc Lights on Low Potential Circuits:—

a. Must be connected with main conductors only through a double-pole cut-out and a double-pole switch, which shall plainly indicate whether "on" or "off."

b. Must only be furnished with such resistances or regulators as are inclosed in non-combustible material, such resistances being treated as stoves. Incandescent lamps must not be used for resistance devices.

c. Must be supplied with globes and protected as in the case of arc lights on high-potential circuits.

29. Electric Gas Lighting:—

Where electric gas lighting is to be used on the same fixture with the electric light—

a. No part of the gas piping or fixture shall be in electrical connection with the gas-lighting circuit.

b. The wires used with the fixtures must have a non-inflammable insulation, or, where concealed between the pipe and shell of the fixture, the insulation must be such as required for fixture wiring for the electric light.

c. The whole installation must test free from "grounds."

d The two installations must test perfectly free from connection with each other.

30. Sockets:—

a. No portion of the lamp socket exposed to contact with outside objects must be allowed to come into electrical contact with either of the conductors.

b. In rooms where inflammable gases may exist, or where the atmosphere is damp, the incandescent lamp and socket should be inclosed in a vapor-tight globe.

31. Flexible Cord:—

a. Must be made of two-stranded conductors, each having a carrying capacity equivalent to not less than a No. 16 B. & S. wire, and each covered by an *approved* insulation, and protected by a slow-burning, tough, braided outer covering.

Insulation for *pendants* under this rule must be moisture and flame-proof.

Insulation for *fixture* work must be waterproof, durable and not easily abraded.

Insulation for cords used for all other purposes, including portable lamps and motors, must be solid, at least $\frac{1}{32}$ of an inch in thickness, and must show an insulation resistance between conductors and between either conductor and the ground of at least one megohm per mile, after one week's immersion in water at 70 degrees Fahrenheit, with a current of 550 volts, and after three minutes' electrification.

b. Must not sustain more than one light not exceeding 50 candle-power.

c. Must not be used except for pendants, wiring of fixtures and portable lamps or motors.

d. Must not be used in show windows.

e. Must be protected by insulating bushings where the cord enters the socket. The ends of the cord must be taped to prevent fraying of the covering.

f. Must be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

g. Must be equipped with keyless sockets as far as practicable, and be controlled by wall switches.

32. Decorative Series Lamps:—

Incandescent lamps run in series circuits shall not be used for decorative purposes inside of buildings, except by special permission in writing from the Underwriters having jurisdiction.

CLASS D, ALTERNATING SYSTEMS.

CONVERTERS, OR TRANSFORMERS.

33. Converters:—

a. Must not be placed inside of any building, except the Central Station, unless by special permission of the Underwriters having jurisdiction.

b. Must not be placed in any but metallic or other non-combustible cases.

c. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial insulating support

34. In those cases where it may not be possible to exclude the Converters and Primary Wires entirely from the Building, the following precautions must be strictly observed:—

Converters must be located at a point as near as possible to that at which the primary wires enter the building, and must be placed in an inclosure constructed of, or lined with, fire-resisting material; the inclosure to be used only for this purpose, and to be kept securely locked, and access to the same allowed only to responsible persons. They must be effectually insulated from the ground, and the inclosure in which they are placed must be practically air-tight, except that it shall be thoroughly ventilated to the out-door air, if possible, through a chimney or flue. There should be at least six inches air space on all sides of the converter.

35. PRIMARY CONDUCTORS:—

a. Must each be heavily insulated with a coating of moisture-proof material from the point of entrance to the transformer, and, in addition, must be so covered and protected that mechanical injury to them, or contact with them, shall be practically impossible.

b. Must each be furnished, if within a building, with a switch and a fusible cut-out where the wires enter the building, or where they leave the main line. These switches should be inclosed in secure and fireproof boxes, preferably outside the building.

c. Must be kept apart at least ten inches, and at the same distance from all other conducting bodies when inside a building.

36. SECONDARY CONDUCTORS:—

Must be installed according to the rules for "Low-Potential Systems."

CLASS E, ELECTRIC RAILWAYS.

37. All rules pertaining to arc-light wires and stations shall apply (so far as possible) to street railway power stations and their conductors in connection with them.

38. POWER STATIONS:—

Must be equipped in each circuit as it leaves the station with an *approved* automatic "breaker," or other device that will immediately cut off the current in case the trolley wires become grounded. This device must be mounted on a fireproof base, and in full view and reach of the attendant.

Automatic circuit breakers should be submitted for *approval* before being used.

39. TROLLEY WIRES.—

a. Must be no smaller than No. 0 B. & S. copper or No. 4 B. & S. silicon bronze, and must readily stand the strain put upon them when in use

b. Must be well insulated from their supports, and in case of the side or double pole construction the supports shall also be insulated from the poles immediately outside of the trolley wire.

c. Must be capable of being disconnected at the power house, or of being divided into sections, so that in case of fire on the railway route the current may be shut off from the particular section and not interfere with the work of the firemen. This rule also applies to *feeders.*

d. Must be safely protected against contact with all other conductors.

40. CAR WIRING :—

Must be always run out of reach of the passengers, and must be insulated with a waterproof insulation.

41. LIGHTING AND POWER FROM RAILWAY WIRES :—

Must not be permitted, under any pretense, in the same circuit with trolley wires with a ground return, nor shall the same dynamo be used for both purposes, except in street railway cars, electric car houses, and their power stations.

42. CAR HOUSES :—

a. Must have the trolley wires properly supported on insulating hangers.

b. Must have the trolley hangers placed at such a distance apart that in case of a break in the trolley wire, contact cannot be made with the floor.

c. Must have cut-out switch located at a proper place outside of the building, so that all trolley circuits in the building can be cut out at one point, and line circuit breakers must be installed, so that when this cut-out switch is open the trolley wire will be dead at all points within 100 feet of the building. The current must be cut out of the building whenever the same is not in use, or the road not in operation.

d. Must have all lamps and stationary motors installed in such a way that one main switch can control the whole of each installation (lighting or power), independently of main feeder switch. No portable incandescent lamps or twin wire allowed, except that portable incandescent lamps may be used in the pits; connections to be made by two approved rubber-covered flexible wires, properly protected against mechanical injury; the circuit to be controlled by a switch placed outside of the pit.

e. Must have all wiring and apparatus installed in accordance with rules under Class B.

f. Must not have any system of feeder distribution centering in the building.

g. Must have the rails bonded at each joint with not less than No. 2 B. & S. annealed copper wire; also a supplementary wire to be run for each track.

h. Must not have cars left with trolley in electrical connection with the trolley wire.

43. Ground Return Wires :—

Where ground return is used it must be so arranged that no difference of potential will exist greater than 5 volts to 50 feet, or 50 volts to the mile between any two points in the earth or pipes therein.

CLASS F, ELECTRIC HEATERS.

44. Electric Heaters:—

a. If stationary, must be placed in a safe situation, isolated from inflammable materials and treated as stoves

b. Must have double-pole *indicating* switches and double-pole cut-outs arranged as required for electric light or power of same potential and current.

c. Must have the attachments of feed wires to the heaters in plain sight, easily accessible, and protected from interference, accidental or otherwise.

d. The flexible conductors for portable apparatus, such as irons, etc., must have an insulation that will not be injured by heat, such as asbestos, which must be protected from mechanical injury by an outer substantial braided covering, and so arranged that mechanical strain will not be borne by the electrical connections.

CLASS G, STORAGE OR PRIMARY BATTERIES.

45. Storage or Primary Batteries:—

a. When current for light and power is taken from primary or secondary batteries, the same general regulations must be observed as applied to similar apparatus fed from dynamo generators developing the same difference of potential.

b. All secondary batteries must be mounted on *approved* insulators.

Insulators for mounting secondary batteries, to be *approved*, must be non-combustible, such as glass, or thoroughly vitrified and glazed porcelain.

c. Special attention is directed to the rules for rooms where acid fumes exist.

d. The use of any metal liable to corrosion must be avoided in connections of secondary batteries.

MISCELLANEOUS.

46. Miscellaneous:—

a. The wiring in any building must test free from grounds: *i. e.*, each main supply line and every branch circuit should have an insulation resistance of at least 100,000 ohms, and the whole installation should have an insulation resistance between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) of not less than the following:—

Up to	10 amperes	4,000,000
"	25 "	1,600,000
"	50 "	800,000
"	100 "	300,000
"	200 "	160,000
"	400 "	80,000
"	800 "	22,000
"	1,600 "	11,000

All cut-outs and safety devices in place in the above.

Where lamp sockets, receptacles and electroliers, etc., are connected, one-half of the above will be required.

b. Ground wires for lightning arresters of all classes, and ground detectors must not be attached to gas pipes within the building.

c. Where telephone, telegraph or other wires connected with outside circuits are bunched together within any building, or where inside wires are laid in conduit or duct with electric light or power wires, the covering of such wires must be fire-resisting, or else the wires must be inclosed in an air-tight tube or duct.

d. All aerial conductors and underground conductors, which are directly connected to aerial wires, connecting with telephone, telegraph, district messenger, burglar-alarm, watch-clock, electric time and other similar instruments, must be provided near the point of entrance to the buildings with some *approved* protective device which will operate to shunt the instruments in case of a dangerous rise of potential, and will open the circuit and arrest an abnormal current flow. Any conductor normally forming an innocuous circuit may become a source of fire hazard if crossed with another conductor, through which it may become charged with a relatively high pressure.

Protectors must have a non-combustible, insulating base, and the cover to be provided with a lock similar to the lock now placed on telephone apparatus or some equally secure fastening, and to be installed under the following requirements:—

1. The protector to be located at the point where the wires enter the building, either immediately inside or outside of the same. If outside, the protector to be inclosed in a metallic, waterproof case.

2. If the protector is placed inside of building, the wires of the circuit from the support outside to the binding posts of the protector to be of such insulation as is approved for service wires of electric light and power, and the holes through the outer walls to be protected by bushing the same as required for electric light and power-service wires.

3. The wire from the point of entrance to the protector to be run in accordance with rules for high potential wires: *i. e.*, free of contact with building and supported on non-combustible insulators.

4. The ground wire shall be insulated, not smaller than No. 16 B. & S. gauge. This ground wire shall be kept at least three (3) inches from all conductors, and shall never be secured by uninsulated double-pointed tacks.

5. The ground wire shall be attached to a water pipe, if possible; otherwise may be attached to a gas pipe. The ground wire shall be carried to and attached to the pipe outside of the first joint or coupling inside the foundation walls, and the connection shall be made by soldering, if possible. In the absence of other good ground, the ground shall be made by means of a metallic plate or a bunch of wires buried in a permanently moist earth.

e. The metallic sheathes to cables must be permanently and effectively connected to "earth."

f. The following formula for soldering fluid is suggested :—

Saturated solution of zinc	5 parts
Alcohol	4 parts
Glycerine	1 part

WIRES.

The following is a list of wires which have been tested and found to comply with the standard for *approved* wires, required for *all* high-potential work (300 volts or over); and for service wires, all classes of concealed wiring and wiring exposed to dampness in low potential work :—

Name of Wire.	*Manufacturer.*
Americanite	American Electrical Works.
Bishop	Bishop Gutta Percha Co.
Clark	Eastern Electric Cable Co.
Climax	Simplex Electric Co.
Simplex (caoutchouc)	Simplex Electric Co.
Crescent	John A. Roebling's Sons Co.
Crown	Washburn & Moen.
Globe	Washburn & Moen.
Salamander	Washburn & Moen.
Crefeld	Crefeld Electrical Works.
Grimshaw (White core)	N. Y. Insulated Wire Co.
Raven core	N. Y. Insulated Wire Co.
Requa (White core)	Safety Insulated Wire & Cable Co.
Safety (Black core)	Safety Insulated Wire & Cable Co.
Habirshaw (White core)	Ind. Rubber & Gutta Percha Ins. Co.
Habirshaw (Blue core)	Ind. Rubber & Gutta Percha Ins. Co.
Habirshaw (Red core)	Ind. Rubber & Gutta Percha Ins. Co.
Paranite	Indiana Rubber & Insulated Wire Co.
Liberty	Atlas Covering Works.
Kerite	W. R. Brixey.
Okonite	Okonite Co.
Paracore	Nat. India Rubber Co.
N. I. R.	Nat. India Rubber Co.
U. S.	Gen. Electric Co.
Columbia	C. S. Knowles.

NOTE.—The results of recent tests on these and other wires can be seen at inspection offices.

MATERIALS.

The following are given as a list of NON-COMBUSTIBLE, NON-ABSORPTIVE, INSULATING materials, and are listed here for the benefit of those who might consider hard rubber, fiber, wood and the like as fulfilling the above requirements. Any other substance, which it is claimed should be accepted, must be forwarded for testing before being put on the market:—

1. Glass.
2. Marble (filled).
3. Slate without metal veins.
4. Porcelain, thoroughly glazed and vitrified.
5. Pure Sheet Mica.
6. Lava (certain kinds of).
7. Alberene stone.