MOTION PICTURE ELECTRICITY

By J. H. HALLBERG

PUBLISHED BY
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Pullman Building :: 17 Madison Avenue
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The Author

IN an issue of the Electrical World of July 15, 1905, the following biographical sketch was first published:

"Josef Henrik Hallberg was born in Falkenberg, Sweden, in the year 1874. In the spring of 1890 he graduated from Latin-Laroverket, Halmsted, Sweden. Shortly thereafter he came to America, and in October of the same year entered the Ottumwa Iron Works, Ottumwa, Iowa, as apprentice in the machinist trade. During the three years of his apprenticeship he gained much practical experience in building and testing, erecting and operating steam engines, coal mining and hoisting machinery.

"After completing the apprenticeship course in 1893, he became associated with Kohler Brothers, contracting engineers in Chicago, which connection he severed in 1894 to accept a position as sales engineer with the Electric Appliance Company, of Chicago, with which company he remained until 1896. For three years, or until 1899, he served as electrical engineer and designer for the Standard Thermometer & Electric Company, Peabody, Mass.

"From 1899 until 1903 he was electric engineer and designer with the General Incandescent Arc Light Company, New York. While with this company he patented and developed a complete line of modern enclosed arc lamps, alternating-current regulators, automatic transformers, switchboards and protecting devices. He has also engineered many important street lighting installations, the most notable of which is the street lighting system in Cincinnati, O., which is remarkable in that there are installed about 6,000 4-ampere series alternating-current arc lamps which require over 105 separate circuits, with transformers, regulators and switchboards located in sub-stations. This is the largest arc lighting installation in the world using series alternating-current arc lamps.

"In 1903 Mr. Hallberg was appointed general superintendent and electrical engineer for the Cincinnati Gas & Electric Company, with full charge of its electric power stations and distribution system, comprising about 30,000 horse-power of steam and electric equipment and a large storage battery. While in charge of this plant he made many important changes in the methods of operating the power plants and the storage battery, considerably reducing losses and operating expenses. In the early part of 1904, Mr. Hallberg was elected vice-chairman of the Cincinnati Chapter of the American Institute of Electrical Engineers, in which capacity he acted during that year.

"In 1904 Mr. Hallberg established an office in New York City as consulting engineer. He has been retained as consulting and advisory engineer to the Commission on Municipal Electric Lighting of New York City, and has been appointed consulting expert for the National Carbon Company, Cleveland, O., in all matters relating to carbon for electrical purposes. He has also been retained as consulting engineer by several large lighting and power, industrial and manufacturing plants.

"Mr. Hallberg is the author of numerous technical papers and articles. He is the inventor and patentee of electrical apparatus and systems, among which may be memtioned a single-phase to poly-phase alternating-current trunk line electric railway system. He is an associate member of the American Institute of Electrical Engineers, an associate member of the National Electric Light Association and a member of the Swedish Engineers' Club of America."

About six years ago, to bring the story down to date, Mr. Hallberg became interested in motion picture theaters through the granting to him of a patent on his electric "Economizer" and on flaming arc lamps, special terminals and connections for use in picture houses.

Through his ability Mr. Hallberg has filled the position of consulting engineer for many large manufacturing establishments. Among these are the Atlantic Mills, of Providence, R. I.; A. D. Juilliard & Co., New York; National Carbon Company, Cleveland, O.; Standard Silk Company, Phillipsburg, N. J.; Stanley G. I. Electric Manufacturing Company, Pittsfield, Mass. and Jacob Rupert Brewing Company, New York.

He was selected by Horatio A. Foster, editor of "Foster's Electrical Engineer's Pocket-Book" to write the chapter on "Arc Lamps and Arc Lighting" for that publication, which is the guide and reference book consulted by all electrical engineers. It is also worthy of note that Mr. Hallberg has lectured frequently at the University of Columbia on electrical subjects.

Foreword

THE motion picture industry has within a very short time expanded to such tremendous proportions that the call for experienced managers and operators has been greater than the supply. Mechanics and electricians, in general, have qualified themselves as motion picture operators. There are, however, conditions to be met with in practice which require special knowledge in this particular line.

In order, in a measure, to assist the operator in securing education concerning the fundamental principles involved and the best methods of getting perfect results, the writer herewith presents a reproduction of his "Electrical Talks," which appeared in the Film Index some time ago. There is also included additional new matter and valuable data and tables which will be of interest to the proprietor, manager and operator of motion picture theaters.

The day has passed when "any old thing goes." The public insists upon perfect pictures and perfect projection, and it is incumbent upon each individual proprietor to meet this demand. The operator is the man behind the gun—he has to stand the brunt if the picture is not brilliant and if things don't go right generally, as far as the picture is concerned. He is the man whom I want to, and can assist, and a careful study of the following pages will make many operators better qualified to secure ideal results.

I do not contend that there are not other ways to accomplish results than those set forth within these pages, but I do claim that if these instructions are followed the best results will be obtained.

Mr. Manager: You are conducting one of the most beneficial and educational institutions of the country.

Every motion picture theater, properly conducted, is, as I might say, a recreation and resting place for the overworked brain and from an educational and amusement point of view it has no parallel because you teach without language through the eye to the brain by means of motion and acting, making everybody, foreigner or native, understand alike. Therefore, you must do your part to make this transmission of intelligence without words as clear, easy and restful as possible by making your picture stand out bold, steady and clear on your screen.

Publishers' Note

Following a plan outlined a few years since, the publishers of The Moving Picture World take pleasure in adding this volume to their standard publications for the moving picture industry.

This book covers the very important end of the picture theater electrical equipment. Its author is well known throughout the trade, and through his extensive experience is particularly well equipped for the preparation of this volume.

The publishers trust and believe the book will prove a valuable help. It contains complete, practical and technical information which should answer the requirements of every reader, as well as standard tables of electrical and kindred subjects that are in constant use in the trade. We consider each department in this publication to be of the highest possible worth to those interested in motion picture exhibiting. Therefore, we highly recommend it as a technical authority.

CHALMERS PUBLISHING COMPANY

July, 1914

Technical Section

CHAPTER I

Electricity

THAT magnificent and most wonderful force or power, which almost runs the world, has in no little measure contributed to the phenomenal success of the motion picture industry. In justice to yourself, to your business and to your patrons, you must become more familiar with the functions and the general application of electricity in your theater so that you may economize and improve the results to the greatest possible extent.

There is no substitute, at the present moment at least, for the electric current as a means for advertising your place of business; illuminating your theater and for projecting brilliant pictures.

The economical application and most practical selection of the many different kinds of current and appliances for motion picture theaters is not so thoroughly and generally understood by the average electrician as one would believe. Experience in all branches of the electrical business, including designing and manufacturing electrical apparatus, electric wiring, installation of electrical machines, ventilating systems and fittings of all kinds, generating and distributing electric current, and last but not least, thorough knowledge of the requirements of motion picture theaters in particular, must be the accomplishments of your electrical advisor.

The most difficult part of my problem will be to make everything clear and plain to you, but I am sure that if you will carefully read each line you will understand; read it again and again so that you will remember it.

Before discussing electrical equipment in detail, we will first become familiar with the meaning of electrical terms and names.

VOLTAGE

Voltage is the word which signifies the pressure of the electric current on or in an electric circuit.

Voltage is also represented by any of the following words which practically mean the same thing: Potential, Electro-Motive-Force, Electric Pressure. These are the most common.

Voltage represents the pressure of an electric system or service just the same as pounds per square inch represents the pressure in a water, steam or compressed air pipe.

To give you a practical illustration by which you can judge voltage, I may say that an ordinary electric battery such as used for telegraph and fire alarm systems gives a pressure of just about one volt. Now if we take 110 such batteries and connect them in series one after the other, we will have between the first and the last wire a potential or voltage of 110 volts.

Electric batteries which produce electric current by means of chemical action are not practical for heavy or continuous work, therefore, electric dynamos or generators, which produce almost any desired voltage and current by the use of mechanical power to drive such generators are necessary and are universally used for the supply of current on a large scale.

TESTING VOLTAGE

Voltage is measured by a volt meter, which may be attached to the two wires to be tested. Another method of testing voltage roughly is to connect two incandescent lamps of the same candle power, each one of 110 volts, in series. If both lamps burn bright, that is, giving the normal candle power, you know that the circuit delivers about 220 volts. If the lamps burn very dim, giving only one-quarter of the normal candle power, the circuit delivers about 110 volts. This method of testing with lamps is not recommended as being accurate or final, but may be used by the traveling exhibitor in determining for himself before he connects his machine circuit, whether the 110 or 220 volt rheostat should be used.

Suppose you have a water pipe one mile long and at the end of it there is a faucet and just ahead of the faucet a water pressure gauge is connected to the pipe, and the gauge indicates 110 pounds. Now open the faucet and you will see that the pressure gauge needle will fall back, depending upon the size of the pipe and how wide you open the faucet. If the pipe is very small, the friction which the water creates in flowing against the wall of the pipe will cause the pressure at the end to drop very low.

Just so is the voltage of a circuit affected. If you have two small wires running a distance of a mile and at the end of the wires we connect an arc lamp, a quantity of incandescent lamps, or a motor, the voltage, when the arc lamp is not burning, is 110. When the load is switched on, the voltage may drop very low if the wires are not large enough, due to the friction or resistance offered by the wire to the flow of current; and it is evident that the arc lamp, the incandescent lamps, or the motor at the end of your wires will not operate properly. I believe that the foregoing explanation will give you a good idea of the word or term voltage.

AMPERE

Ampere is the word which signifies the quantity or volume of electricity flowing through an electric circuit, arc lamp, incandescent lamp, motor or other machine, connected to the circuit.

The measurement called "gallon" in the water system, or cubic foot for gas, designates quantity or volume. So does the ampere in the electric system.

Remember, at the end of the water pipe referred to under the heading "Voltage," page 10, we had a pressure of 110 pounds on the gauge when no water was flowing and also at the end of the electric circuit we had 110 volts when the wires were not connected to the arc lamp, or other load. The reason why the water gauge showed full 110 pounds or the volt meter 110 volts, at the end of the pipe line or the electric circuit, was that the faucet was closed or the electric wires were not connected to a load. There were no gallons of water flowing through the pipe and there were no amperes flowing through the electric wires, consequently no work was done and there simply remained the pressure at the end of the pipe or at the end of the wires ready to do work.

As the diameter of the pipe has to be larger in order to carry more gallons of water, so does the electric wire have to be larger in order to carry more amperes. Otherwise the friction in the pipe or the resistance in the wire will use up the pressure or voltage before we get to the faucet or to the arc lamp, making the flow of gallons very low or the flow of amperes much less than it ought to be. From the above, you can make up your mind that:

> The size of the wire required for an electric circuit depends entirely upon the number of amperes required for the electric installation.

To give you an idea of the general amount or volume of an ampere I might tell you that one 16 c.p. carbon filament lamp on 110 volts requires about one-half ampere; one regular enclosed arc lamp, such as are usually furnished by the electric lighting companies, requires about 5 amperes on 110 volts; one d. c. arc lamp for motion picture machine requires about 30 amperes.

OHM

Ohm is the word or electrical term which signifies the unit of resistance offered to the passage or transmission of an electric current on or through an electric wire or conductor.

> The legal ohm is the resistance of a mercury column one square millimeter in cross sectional area and 106 centimeters in length.

The ohm represents, in other words, "resistance" of electric conductors and machines and stands for the same thing as the friction in a pipe carrying water, gas or air,

In everyday discussion of electrical matters by the user of electrical machines, the word ohm is not employed, but the word resistance being more common and easily understood is generally used.

Under the heading "Voltage," page 10, we discovered that the voltage at the end of an electric circuit may be considerably lower than the voltage at the point where the current is generated and that the voltage drop was due to the flow of ampere through the circuit, in other words to the friction or resistance offered by the wire to the flow of current. The voltage was used up in pushing the current through the wire just the same as water pressure is used up in pushing water through a pipe. When anything is moved from one point to another there is a loss depending upon the resistance offered. For instance, if you wish to move a 100-pound weight from one point to another it induces a loss of power or energy depending upon the friction or resistance which, however, can be modified by using different means for reducing or increasing the friction. If the 100-pound weight is set on a rough board it is difficult to move it because the rubbing of the weight against the board causes friction and the rougher the board the greater the friction and consequent power required to move the weight. This power is lost in the shape of heat, generated on the two rubbing of the weight against the board causes friction smooth less power would be required in moving the weight because the friction and consequently the heat loss is less. If we mount the weight on wheels or ball-bearings then much less power would be required in effecting the movement because the friction is then reduced to a minimum.

This example serves us very well in getting a clear understanding of resistance due to friction in moving anything from one point to another. Just so is the resistance or friction with consequent loss generating heat in electric wires and machines due to the resistance offered by the wire to the passage of the current, depending upon;

(1) The size or diameter of the wire.
(2) The material from which the wire is made.
(3) The amount of current in amperes to be forced through the wire.

We now understand that whenever resistance is introduced heat is generated and power is lost; therefore, we should reduce the resistance in all electric circuits and machines to the lowest possible amount in order to save electric energy which costs money to produce.

Copper is the material which for practical purposes offers the least resistance to the passage of electrical currents; therefore copper is used for conducting wires and for all kinds of electrical machine windings.

If we want to generate heat by means of electricity, then we introduce a wire made of some other material than copper, which offers greater resistance to the passage of electric current as is the case in electric heaters which are made of porcelain, with a wire made of nickel and copper, or nickel and steel, wound upon the porcelain through which the current passes, thus heating the wire.

If we wish to produce light with electricity, then for the incandescent or glow lamp there must be used a wire or conductor of very high resistance which glows yellow or white, depending upon the style of the lamp.

If still more brilliant light is required it may be produced by the electric arc between two metal or carbon points. In this case, the resistance is the air space between the two points, which is so great that the current ordinarily used for electric lighting cannot jump across even the smallest air gap. In this case, the carbons must be put in actual contact before the "arc" can be started, and then the heat vaporizes the points which forms a gas, to take the place of the air, and this gas maintains the "arc" and permits the separation of the points forming what is ordinarily called an "arc light."

In order to give you an idea of the comparative resistance of different kinds of materials, I will mention them in the following order from the lowest to the highest: Silver, copper, brass, zinc, iron, nickel, carbon, plumbago, moist earth and water.

You may be surprised to learn that if I take a copper rod one-half inch in diameter, 10 feet long and take a glass pipe one-half inch inside diameter, 10 feet long, filled with water, the resistance of the water in that pipe is to electricity 6,754 million times greater than the resistance of the copper rod.

This may surprise some motion picture operators who have been using water for resistance in place of a rheostat, but it is nevertheless a fact that water cannot be used for a rheostat, unless something else, like salt, for instance, is put into the water in order to lower its resistance, as otherwise you could not force any current through the water rheostat.

Operators who have used the earth as a resistance by driving pipes into the ground, or by putting metal plates on the bottom of a pond or lake, get a current through the moist earth and not through the water, unless the water is salt or is in some other way made a conductor.

There are two kinds of resistance; one is due to the friction offered by the conductor, or wire, to the flow of the current which is usually called "Ohmic Resistance."

The other kind of resistance is due to the magnetic kick, or reaction, in an electric circuit or machine and is usually called "Inductive Resistance."

While it is present with direct current systems it is not noticeable unless in special cases, but it is always a big factor when alternating current is used, and it is taken advantage of in several ways in order to do away with the rheostat for the control of arc lamps, as will be referred to later on.

WATT

Watt is the word which expresses the unit of electric power. One thousand watts are called one kilowatt and when one kilowatt is used for one hour a certain quantity of power has been produced and used, which is called one "kilowatt hour."

In order to abbreviate these terms kilowatt is written and spoken of as k.w. and the kilowatt hour k.w.h.

The kilowatt hour is the unit or measure by which electric power is made and sold, and this term is used all over the world.

The watt is the product or effect of voltage multiplied by amperes. For instance, if we have a circuit on which there is a voltage of 100, and we operate a moving picture arc lamp on direct current, taking 30 amperes, we multiply 100 by 30, which gives us 3,000 watts, which equals 3 kilowatts, or in abbreviated form 3 k.w. If we burn this arc lamp for one hour there will be consumed 3 kilowatt hours, therefore if the rate is 10 cents per k.w.h. it would cost just 30 cents for one hour.

If we burn this same arc lamp only one-half hour it is evident that the watt consumption will be just one-half or 1,500, which equals 1½ k.w.h. and the bill for electric current will therefore also be one-half, or 15 cents.

Electricity is different from all other powers or forces because it cannot be measured by volume, but only by its effect.

When you buy water from the water company you get *pressure* as well as *a certain number of gallons* of water. The *pressure* may be used for driving a water motor or lifting a piston elevator and besides you have *the original number of gallons of water left after the work has been done.*

When you buy electricity from the electric lighting company, you secure and pay for a certain effect which may be represented by power, heat or light, but after you have secured this effect you have nothing left. In other words there is no evidence of you having received anything but the work done on the instant.

In order to give you a practical understanding of what you get when you purchase 1 k.w.h., I may say that 1 h.p. as usually applied to a steam engine equals exactly 746 watts, or three-quarters of a k.w. If you operate a 1 h.p.

steam engine for one hour you have used 1 h.p. hour, and for an ordinary engine this would require about 10 pounds of coal.

Now, if you substitute a 1 h.p. electric motor for the 1 h.p. steam engine the motor will require about 746 watts, or three-quarter k.w.h. to do the same work, and the expense at the 10 cent rate would be just 7½ cents for one hour's operation.

I am giving you these examples in order that you may have it impressed upon your mind that electric power is in many respects similar to steam or water power and also to get you familiar with the comparative values of electricity.

The ohm is the unit for measuring resistance in electric circuits and machines.

Resistance is that property in a wire or other material which opposes a movement of any kind and is generally applied to represent the friction in an electric wire. The resistance should be kept as low as possible in order to reduce the heat loss and consequent expense for electric power uselessly wasted.

The kilowatt hour is the unit of measurement for electric power, and is the product of the voltage multiplied by the amperes for all direct current systems.

KILOWATT HOUR

Before going into details as to how to figure kilowatt hours from voltage and amperes, I will give you further explanation.

Suppose you hire a man capable of pumping sufficient water to fill a tank on your roof, and that it takes this man working with normal power and exertion ten hours to do the work, and you pay the man $1.50 or 15 cents per hour. At that rate you are paying 15 cents for each man hour. If you wanted to do this same work in one hour's time, you would have to put in ten pumps, employ ten men and at the rate of 15 cents per hour, the total expense would be just $1.50, but you would have the work done in just one-tenth of the time and the only extra expense to you would be the investment for the nine extra pumps, providing you could get the ten men just when you want them.

It is generally agreed that one man power equals about one-eighth to one-fourth horse-power, depending upon the length of time the man is compelled to work. In other words, a man can produce about one-eighth horse-power continuously for ten hours. It is, of course, understood that he may have to rest for a while, but no man can produce one-fourth horse-power continuously, only for a period of one-half hour, unless in exceptional cases.

We have learned that one horse-power equals about three-fourths k.w., but allowing for all losses in the motor and the belt it takes about one k.w.h. to produce one horse-power. Therefore, one-eighth of a horse-power would require just one-eighth of a k.w., or 125 watts per hour.

If we put an electric motor on the above mentioned pump, it would consume about 125 watts per hour, which for ten hours would be 1,250 watts or 1¼ k.w., which at the 10 cent rate would represent an expense for current of 12½ cents. This one-eighth horse-power motor would have to run steady for ten hours to do the work, and you understand, of course, that the electric light company would have to furnish boiler, engine, dynamo, feed wires, transformer and meter large enough to drive this one-eighth horse-power motor and that the electric company would furnish you this quantity of power in ten hours' time, giving them a good, steady load at the expense to you of 12½ cents.

Now, if you want to do this work in one hour, you would have to put in about 1¼ horse-power motor and you can readily understand that the electric light company would have to put in much larger electric generating equipment in order to supply you at the same 10 cent rate for current, the income to the electric company would be just about 12½ cents, but the expense would be much greater because the company has to invest more money and run a bigger plant if you want your work done in one hour.

That is the reason for the electric company in many places charging according to the number of hours you use your installation; therefore, when you put in your equipment you must do it in such a way that you have the smallest possible amount of installation or, as I might call it, "demand" on the electric company's service, in order to secure the lowest rate. The current saver for the motion picture machine lamp cuts your demand in half, not only cutting your old bill 50 per cent., but in some instances also reducing the rate, if the electric company has a rate on the sliding scale, as many of them have.

We all know that it costs more to put up a building in two months than to put it up in six months, because rush work means more expense in every way, and I want to impress this on your mind, because in laying out the electric equipment for theaters, considerable reduction can be made in the current consumption as well as in the rate, especially if the company has a sliding scale of rates. I have deemed it advisable to give you the foregoing example, because you must realize and understand these fundamental principles, and any time you spend at familiarizing yourself with the illustrations given will save you a great deal of misunderstanding and expense and it will also give you a clear idea of why the electric light company charges different rates for different classes of service.

As a comparison and standard of values, I will say that:

One 16 c.p. carbon filament lamp takes about 50 watts per hour.

One regular enclosed arc lamp takes about 500 watts per hour.

One 4,000 c.p. flaming arc lamp takes about 500 watts per hour.

One 12-inch fan motor takes about 50 watts per hour.

One 16-inch fan motor takes about 100 watts per hour.

One ceiling fan takes about 125 watts.

One 18-inch exhaust fan takes about 250 watts per hour.

One 24-inch exhaust fan takes about 400 watts per hour.

One 36-inch exhaust fan takes about 1,000 watts per hour, or 1 k.w.

One ordinary moving picture lamp on direct current with rheostat on 110 volts takes about 3,300 watts per hour, or 3 3-10 k.w. This same moving picture lamp on 220 volts takes 6,600 watts or 6 6-10 k.w. per hour.

One moving picture lamp with rheostat on alternating current 110 volt circuit takes 4,500 watts or 4 5-10 k.w. per hour. This same lamp on 220 volts takes 9,000 watts, or 9 k.w. per hour.

Keeping this data in mind, you can easily figure for yourself how many watts or k.w. your installation requires.

FORMULAS

For the electrician and operator as well as the manager or proprietor who may be interested, the following data and formulas are of great value in figuring voltage, amperes, resistance and watts.

Formula No. 1

$$C = \frac{E}{R}$$

Formula No. 1 is the electrical designation for figuring the number of amperes which will pass through a rheostat when you know the voltage and the number of ohms of your rheostat. For instance, if you have a line voltage of 100 and your rheostat has a resistance of 5 ohms and you want to find out how many amperes will pass through the rheostat, the formula extended in simplified form will read:

$$\text{Amperes equals } \frac{100 \text{ volts}}{5 \text{ ohms}}$$, or, written out: 100 volts divided by 5 ohms equals 20 amperes, and this is the amount of current you would get through your rheostat, which would, in that case, be nothing more than an electric heater taking 20 amperes from the 100 volt line.

Formula No. 2

$$R = \frac{E}{C}$$

Formula No. 2 is the electrical designation for figuring the number of ohms for resistance required in your rheostat when you know the line voltage and the number of amperes required for your work. For instance, if you have 100 volts and you require 20 amperes for your work, the formula in simplified form reads as follows:

$$\text{Resistance in ohms of rheostat equals } \frac{100 \text{ volts}}{20 \text{ amperes}},$$

or written out: 100 volts divided by 20 amperes equals 5 ohms, which is the resistance required in your rheostat.

Formula No. 3

$$E = C \times R$$

Formula No. 3 is the electrical designation for figuring the number of volts required to force a certain number of amperes through a rheostat of given resistance. For instance, if you have a flow of 20 amperes through a rheostat offering a resistance of 5 ohms, the formula in simplified form reads as follows:

Voltage equals 20 amperes x 5 ohms, or written out: 20 amperes times 5 ohms equals 100 volts. In other words, it would take just 100 volts to force 20 amperes through a rheostat having a resistance of 5 ohms.

Formula No. 4

$$W = C \times E$$

Formula No. 4 is the electrical designation for figuring the number of watts which will be delivered by a given voltage and flow of amperes on a D. C. and for A. C. where the load is made up of only "ohmic" resistance. It cannot be used correctly for A. C. where motors, arc lamps and current savers are used, as such a load has in addition to "ohmic" resistance what is called "inductive" resistance. For instance, if you have on D. C. system a flow of 20 amperes and the voltage is 100, the formula in simplified form reads as follows:

100 volts x 20 amperes equals 2,000 watts. In view of the last formula, you can easily remember that

> For all D. C. systems it is only necessary to multiply the line voltage by the amperes flowing through the circuit in order to find the number of watts required.

In explanation of these formulas remember the following:

C stands for current in amperes.

E stands for the line voltage or the voltage at the point where test is made.

R stands for resistance, of the rheostat or machine, in ohms.

W stands for watts.

> The amperes flowing through a circuit or machine are equal to the voltage, divided by the resistance in ohms.
>
> The resistance in ohms of a circuit or machine is equal to the voltage divided by the amperes flowing.
>
> The voltage at the terminals of a circuit or machine is equal to current in amperes flowing multiplied by the resistance in ohms.
>
> The watts consumed in a circuit, machine, incandescent or arc lamps are equal to the current in amperes times the voltage at the terminals where the test is made excepting for alternating systems with "inductive" loads.

CHAPTER II

Generation of Current

THERE are two kinds of electric current used for practical purposes, which may be designated as follows:

(1) Direct current.
(2) Alternating current.

Either one of which may be used for electric lighting, heat and power.

DIRECT CURRENT

Direct current, also called continuous current, flows in one direction only and has always two fixed poles, one called "Positive," designated by (+), the other "Negative," designated by (—).

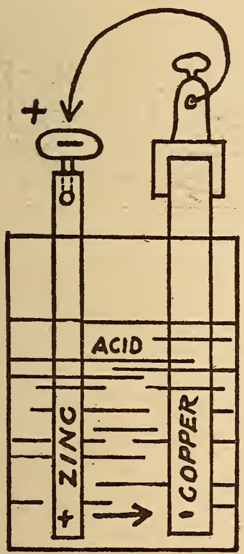


Fig. 1

Direct current may be produced in several ways, the most common by means of the electric battery, which through the action of acid on metals produces electricity in small quantity suitable for telephones, medical batteries, fire alarm systems, door bells, etc., or by means of an electric dynamo or generator driven by a steam engine or other power, as is the practice in the regular electric power stations.

Fig. 1 illustrates an ordinary electric battery usually composed of a glass jar in which is placed two metal elements like zinc and copper, for instance, and the jar is then partly filled with a fiuid composed of sulphuric acid and water in some cases. The action of the acid upon the zinc causes a chemical change to take place, which generates a current flowing from the zinc to the copper, but at the upper end of the electric element or electrodes the current flows from the copper to the zinc, making the copper the positive terminal.

There are many other forms of batteries, for instance the one used for electric bells, in which the elements are made of zinc and carbon with a solution of salamoniac surrounding the elements. You are undoubtedly acquainted with this form of battery, as it is extensively used for door bells, etc.

As already stated, where a large quantity of power is required the chemical method is not practical, therefore a power plant like that illustrated in Fig. 2 is substituted.

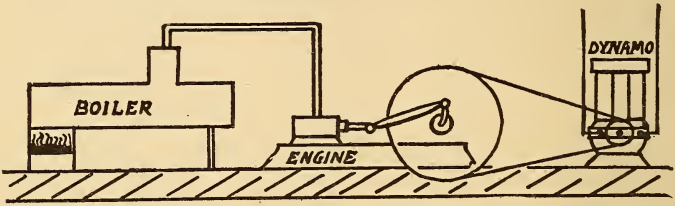


Fig. 2

An electric power plant is usually composed of four distinct parts:

(1) The boiler.

(2) The steam engine.

(3) The dynamo or electri generator.

(4) The switchboard.

The illustration shows in a simple way such an installation without the switchboard.

The D. C. electric generator produces electricity by revolving its armature at high speed under the influence of the magnetism in the stationary magnetic pole pieces or "field," as it is usually called.

Electric generators are now made in all sizes, from the smallest up to 10,000 k.w., these large ones requiring engines approximating 20,000 h.p.

From the generator the current is brought through large copper conductors to a switchboard in the power station, where it is distributed over as many switches as required to circuits running to different parts of the town or city.

Upon the switchboard, which is usually made of marble, there are mounted protective fuses or automatic circuit breakers, switches, volt meter and one or more ampere meters. There is also included a field rheostat for each generator by means of which the voltage may be increased at the power house when the load is heavy in order to overcome the losses of voltage-drop in the feed wires, or to lower the voltage when the load is light, in order to maintain it as constant as possible at the theater or other place where the current is used.

Fig. 3 gives a diagrammatical illustration of an electric generator and a 2-wire distribution system in its simplest form operating a motor, incandescent lamps and arc lamps. The illustration indicates the names of the principal parts of the system and how connections are made.

We have already learned that the further the current has to be transmitted, the greater the drop of voltage in the wires, therefore it takes larger wires to carry a given quantity of amperes a long distance, and this is also one of the reasons why the field rheostat for the generator is necessary at the power house in order to raise the voltage of the generator to overcome the line losses, and it is one of the duties of the dynamo attendant to keep the voltage at the proper amount at all times by means of the field rheostat.

The battery is only suitable for small and intermittent work.

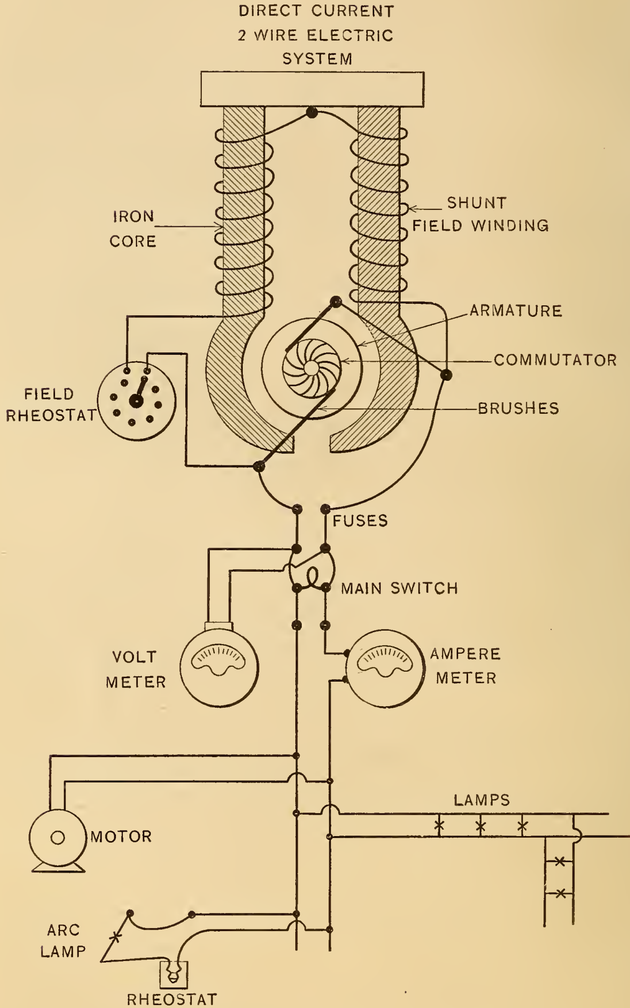

DIRECT CURRENT
2 WIRE ELECTRIC
SYSTEM
IRON
CORE
SHUNT
FIELD WINDING
ARMATURE
COMMUTATOR
FIELD
RHEOSTAT
BRUSHES
FUSES
MAIN SWITCH
VOLT
METER
AMPERE
METER
LAMPS
MOTOR
ARC
LAMP
RHEOSTAT

Fig. 3

Where large current supply is required, it becomes necessary to make the electricity by a dynamo electric machine driven by an engine or similar power.

THREE-WIRE SYSTEM FOR DIRECT CURRENT

The 2-wire direct current distributing system is used, as a general rule, in small plants and in isolated plants where the distance from the electric generator to the point where the current is used is not very great. In a building, for instance, the distance would never be over a few hundred feet, and in a small town the distance from the power station to the furthest consumer might not be over one mile. In such places the 2-wire system may be installed and used, although the cost for copper wire is great as compared with the 3-wire system, which is generally used where a large amount of power is required and where the distance may be several miles, as is the case in the larger towns and cities.

The 2-wire system may be either 110 or 220 volts, but only one of these voltages can be obtained from a 2-wire system, and it is a well-known fact that for electric lighting, 110 volts is more suitable than 220 volts, but where there are a large number of motors and where the distance is great the 3-wire 220-volt system may have to be installed in order to cut down the expense of copper wire between the power house and the place where the current is used.

In order to make a more economical and flexible installation, the 3-wire system is installed, which enables the electric company to transmit the power for motors and lighting on the same wires at half the expense for copper, and, at the same time, to give you 110 as well as 220-volt current.

Fig. 4 illustrates in simplified form the 3-wire system. There are two dynamos or electric generators, A and B, which are connected in series. Both are driven from the

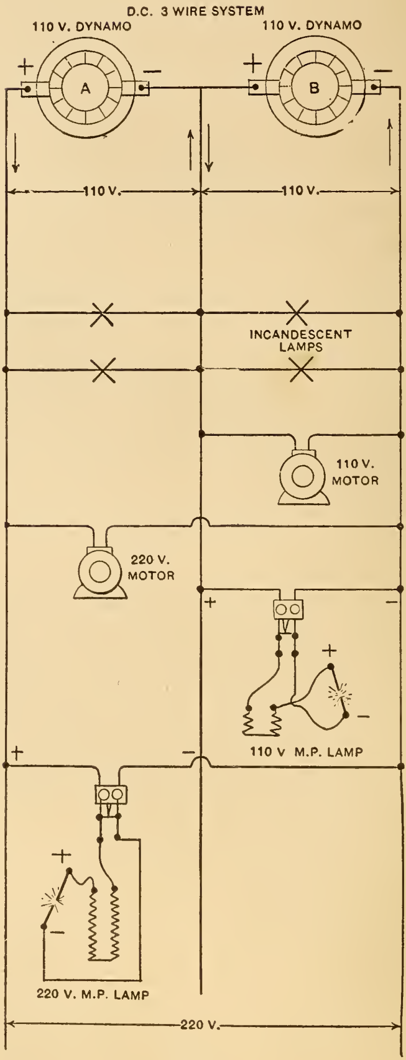

D.C. 3 WIRE SYSTEM
110 V. DYNAMO
110 V. DYNAMO
A
B
+
−
+
−
110 V.
110 V.
INCANDESCENT LAMPS
110 V. MOTOR
220 V. MOTOR
+
−
+
−
110 V M.P. LAMP
+
−
+
−
220 V. M.P. LAMP
220 V.

Fig. 4

same source of power, and each one may be made to generate 110 volts. You will observe that there are three line wires with this system and that while each generator gives only 110 volts, by being connected in series it is possible also to get 220 volts from the same system.

Considering generator A, you observe the current leaves the positive terminal indicated by (+), traveling on the left-hand outside wire to the lamp or motor, through the same and back over the middle wire to the negative terminal of the generator, thus completing the circuit and lighting the lamp or operating the motor.

The same performance takes place on generator B, the current leaving the positive terminal, but in this case going out over the middle wire through the lamp and returns over the outside right-hand wire to the negative terminal of the generator.

It is evident that if we want to maintain the same load on each dynamo, it becomes necessary to balance the load so that there will be just as many amperes taken from one side as the other on this 3-wire system.

In practice this is rather difficult to do in some instances, especially where large arc lamps or motors are used, unless the arc lamps and motors are made for 220 volts so as to operate on the two outside wires, and it is the tendency of the electric lighting companies to make you connect all motors one h.p. and larger, and all arc lamps taking more than 10 amperes on the two outside or 220-volt wires of the 3-wire system, which would otherwise be unbalanced, and would throw more load on one generator than on the other, which should be obviated because it inclines to lower the voltage on the side of the 3-wire system, which has to carry the greatest load. This drop in voltage on one side of the system is especially noticeable with motion picture arc lamps, because they require from 25 to 30 amperes, and draw more than this amount of current from the wire at the instant the carbons are put together in order to strike the arc, and you may have noticed that when the motion picture lamp is started, there is a considerable drop in the candle-power of the incandescent lamps connected to the same side of the system, whereas the lamps on the other side will increase in candle-power, due to the voltage going down on one side and up on the other.

This drop in voltage on one side of the unbalanced 3-wire system is partly due to slipping of the belt on the generator, which supplies the loaded side, and also due to the drop in voltage in the generator and wires supplying that side of the system.

It is obvious that if the moving picture lamp or motor is connected to the outside or 220-volt wires, there is no such disturbance or unbalancing of the 3-wire system, and that is the main reason for the electric lighting company insisting upon having all motion picture arc lamps connected to the 220-volt wires, as they may receive complaints from your neighbors who are fed from the same wires and whose lamps go up and down in candle-power every time the moving-picture lamp is switched on or off.

You are to understand, of course, that if the load is very light, consisting of only a few incandescent lamps, fan motors or small 5-ampere enclosed arc lamps, this unbalancing does not make so much difference, but with large motors, and especially with moving-picture arc lamps, the disturbance on a 3-wire system if operated on one side or on 110 volts is very great and undesirable. By observing the diagram, you will see by the arrows in which direction the current flows, and it is evident that when there are exactly the same number of amperes used on either side of the 3-wire system, the current goes entirely from the outside left to the outside right-hand wire, there being no current flowing over the middle or, as it is called, "neutral" wire.

If, however, there is required ten amperes on one side and only five amperes on the other side of the 3-wire system, there will be five amperes flowing from outside wire to outside wire, and five amperes more will flow on one outside wire and on the neutral wire.

The early electrical systems were all of the direct current type, and so many motors, arc lamps and machines are in service that the electric lighting companies are obliged to continue supplying them with direct current, especially in the manufacturing and business sections of the larger cities, where the distance is not great; but the tendency is to change, as far as possible, to the alternating current system of distribution, which is more economical where long distance is considered. For this reason in the outskirts of the larger towns and cities it is not unusual to find alternating current only, whereas in the center of the city the system is direct current. The more modern plants are all of the alternating type even in the smallest towns, but either system has advantages of its own.

The direct current system is, as a general rule, low voltage, both outside and inside of the building, and is therefore practically harmless, and for certain classes of work, such as small motors and arc lamps, the direct current has the advantage over the alternating in some respects.

> The 3-wire direct current system is generally supplied by two separate generators connected in series.
>
> The current is distributed over three wires, the middle one of which is called the "neutral."
>
> It is essential that on a 3-wire system the load in amperes on either side be kept the same, or as nearly so as possible.
>
> If a 3-wire system has to supply a greater number of amperes on one side than on the other, the side with the greatest load will supply a lower voltage than the other side.

ALTERNATING CURRENT

You have been advised that direct current flows in one direction, and is therefore also called "continuous current," in other words, it flows out over one wire through the lamp or motor, back to the dynamo over the second wire, thus completing the circuit.

Alternating current derives its name from the fact that it alternates, that is, it goes back and forth between the dynamo and the lamp or motor, making a complete reversal of the current many times per second, depending upon what is called the "frequency," also called the "cycles" of the circuit.

In order to make this matter more clear, your attention is called to Fig. 5, which illustrates a water power system. Referring to the illustration: A is an elevated water tank, B is a receiving or storage water tank, C is a pump, G is a water motor. They are all connected by pipes D, E, F and H.

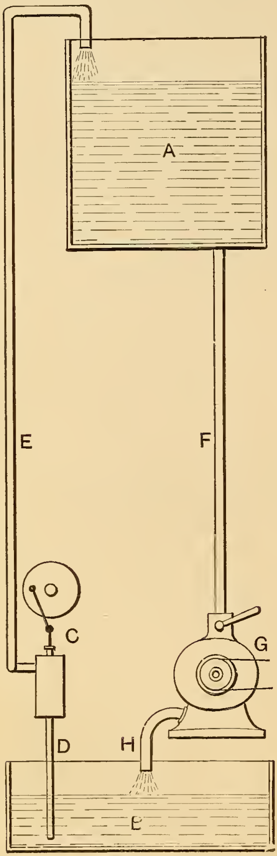


Fig. 5

Suppose we start pump C lifting the water from the lower tank through pipes D and E, filling upper tank A. There will be created a water pressure through pipe F at the motor G. If the starting valve on the motor is open, the water will cause the motor to rotate, discharging through pipe H into the lower tank, thus completing the continuous flow of water, which it takes power to create through the pump C and which is available at another point through the water motor G. This is a good representation of the direct current electric generating system, in which the pump C and the tank A would represent the electric generator and the water motor G, the electric motor.

Fig. 6 illustrates another type of water system in which the flow of water is not continuous. Referring to the illustration: A is the cylinder of an engine having a piston —D, which can exert movement of a crank, shaft and flywheel through the piston rod K. The cylinder A is connected by two pipes E and

F, with another similar pump, cylinder B having a piston C, connected with a piston rod. The operation of this water system is as follows:

By moving the piston rod and consequently the piston C towards J, that is, by pulling it out as if it were connected to a crank, the water J will be compressed and forced up through the pipe F into cylinder A on the side indicated by I, creating a pressure on motor piston D which will, through piston rod K, start the engine backwards. When the piston C has been pulled out to a stop,

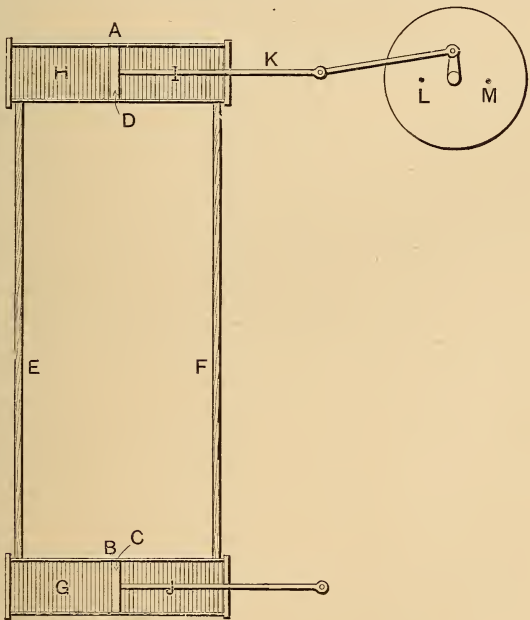


Fig. 6

the water pressure will cease and engine A would stop, but its fly-wheel will carry the crank over the center as it would in any kind of an engine.

If we now push the piston C backwards towards G, the pressure will force the water up through pipe E into the chamber—pushing the piston D and piston rod K towards I—completing the backward motion of the crank, shaft and fly-wheel of the motor A. It is evident that by moving the piston in the cylinder B back and forth the fly-wheel of the motor A can be kept in continuous motion, as the water pressure changes alternately from side I to side H of motor piston D and vice-versa.

Here we have the simplest form of an alternating current water system in which the pump B is the dynamo as compared with an electric system; pipes E and F are the wires and A is the alternating current motor. The process of operation is extremely simple, and the illustrations can be easily understood by reference to the above description and illustration.

Anyone can understand that in Fig. 5 the operation is continuous in one direction being very smooth without interruption and the water motor turns around without oscillating motion and can never stop on a dead center.

With the alternating water system in Fig. 6, however, the movement of the piston in the water motor A is oscillating and the motor cannot be started if the piston is at either one of the extreme ends of the cylinder A. In other words, we have as on any ordinary single cylinder engine, two dead centers, indicated at L and M in Fig. 6.

The alternating current single phase system has exactly the same effect on a motor. It has a dead center on which it is impossible to start the motor unless first revolved by hand or by other means for inducing the starting of the rotating member of the motor are introduced.

Having established in our mind the fact that an alternating current has one or more dead centers or periods when no power is generated or delivered at the instant the current is being reversed, we come to the conclusion that an alternating current is the kind which surges back and forth through the circuit, and while the voltage may be 110, or any other number of volts at a given instant, there are other moments at which time there is absolutely no voltage on the system. It is of course necessary to make these reversals of the current so frequent that, when the current has to be used for electric lighting, there will be no serious interference with the continuity of the light which is more difficult with arc lamps than with incandescent lamps.

> The alternating current is so named because it oscillates or reverses, in other words goes back and forth over the same wires and through the same lamps and motors many times a second.
>
> The alternating current may be of any given voltage, but this voltage is only apparent because at the instant of each reversal of the current there is no voltage generated.
>
> Due to the fact that there are moments of no voltage on an alternating system, it is necessary to make the frequency or change of reversal many times per second in order to maintain the illumination constant.

In order to clearly impress upon your mind the difference between direct and alternating current, I would like to offer one more example:

The Mississippi river gathers the water in the upper part of the country, flowing continuously towards the gulf; the water has a steady, direct flow practically from north to south. A large water-wheel may be set in the river and due to the downward flow of the water it would rotate and produce power. The sun gathers the water from the gulf to the clouds, and the clouds carry the water back again into the upper part of the country from whence it flows; the river thus completing this direct or continuous current water flow.

The lower part of the Hudson river, on the other hand, is a good representation of the alternating current system, because when the tide is low the fresh water flows downward towards the ocean. Within a few hours when the tide rises again, the water flows in the opposite direction against the downward stream of water—actually reversing it. This is an alternating current water system; surging back and forth with the rise and fall of the tide and the cycle of reversal of this current is equal to the rise and fall of the tide. If a large water-wheel should be put in the Hudson river it would turn in one direction when the tide is ebbing; it would then stop for a short time and when the tide begins to rise the water-wheel would be turned in the opposite direction.

This analogy shows you in the simplest possible way how an alternating current, whether represented by water or electricity, actually stands still or rather is inactive at the instant the flow of the current is being reversed; in other words, there is no current, no pressure or no voltage at the instant of current reversal.

Fig. 3 shows a direct-current electric generator having an iron core terminating into two pole pieces called the "field" surrounding part of the rotating armature. There

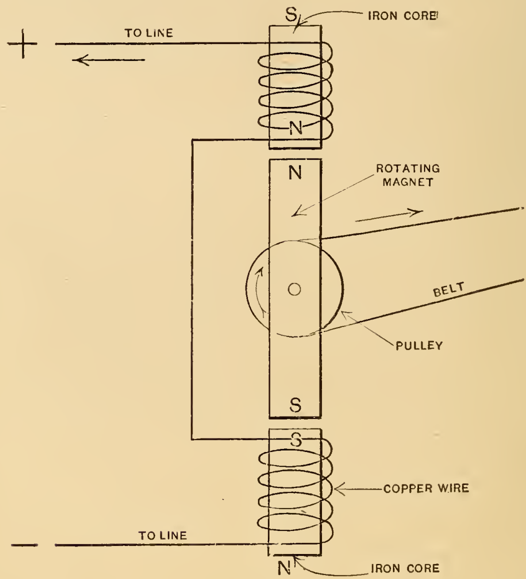


Fig. 7

is also a device mounted on the armature shaft and connected to the armature windings called the "commutator" and there are also two or more brushes which collect the current generated by the armature through the commutator. Practically all direct current generators must be equipped with a commutator, the purpose of which is to keep the current flow in one direction.

An alternating current generator does not require a commutator, and is therefore much simpler in construction and, furthermore, as the commutator can be dispensed with, it is possible to generate a much higher voltage and there is absolutely no chance of sparking.

Fig. 7 illustrates a simple form of the alternating current generator. The rotating magnet is mounted on a shaft which, by means of a pulley and belt, is rotated at high speed between the upper and lower iron cores. These iron cores are surrounded by coils of copper wire which may be connected to the line wires. Suppose the magnet is rotating under the upper iron core in Fig. 7;

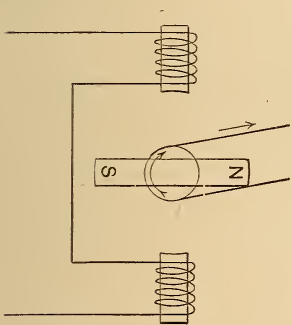


Fig. 8

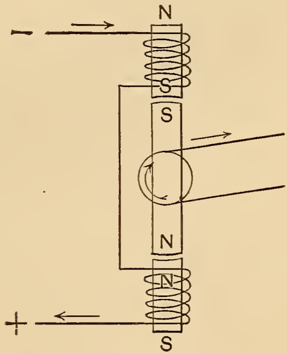


Fig. 9

the iron core will be magnetized to the fullest extent, making the lower end of it a north pole magnet and the upper end a south pole, as indicated by "S." At the instant the rotating south pole "S" is directly over the lower stationary iron core it will be magnetized to the fullest extent south and north as indicated by "S" and "N." As we continue to revolve the magnet we will stop at the position indicated in Fig. 8. At this instant the rotating magnet is exerting no influence on either one of the iron cores.

Continuing the movement of the magnet, we find, as illustrated in Fig. 9, that the magnetism in the upper and lower iron core has been reversed. Going still further, as indicated in Fig. 10, there is again a point or instant when there is no magnetism in the upper and lower iron cores.

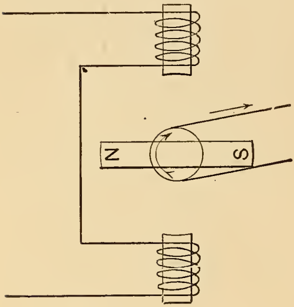


Fig. 10

It may be well to impress upon you the fact that when you rotate or move a magnet towards or from a piece of soft iron, or in fact any kind of iron, the iron will remain magnetized as long as it is under the influence of the magnet, which in the case illustrated is rotating between two soft iron cores.

I want to further impress upon you that when a coil of copper wire is put on a bar or core of soft iron, electric current can be induced or created in the copper coil by suddenly moving a magnet past the end of the soft iron core upon which the coil is mounted.

It is also a fact that if you move the north pole of a magnet past a soft iron core surrounded by a copper wire coil, electricity will be generated in the coil flowing in one direction and if you move this same north pole back and forth the current will be pulsating, but it will always be in the same direction.

Suppose we influence this same core and coil by first moving a north pole magnet past it; the current will flow in one direction. Instead of coming back with the north pole magnet we bring around the south pole, then the magnetism in the soft iron core will be reversed and a current will be generated in the coil, but flowing in the opposite direction.

As it is always easier to secure a rotating motion, dynamos or electric generators for alternating current have the magnet pole pieces mounted on a shaft, and the soft iron cores and the copper wire magnet coils are mounted on a frame surrounding the rotating magnet pole pieces. This arrangement permits sudden and smooth movement of the rotating magnet past the stationary iron cores which are thereby first magnetized in one direction then in the other as fast as the magnet pole pieces are being rotated, and in consequence thereof electric current is generated in the copper wire coils which is then distributed to the line wires.

It is obvious that the magnetism will be strenuous in the iron cores and the current on the line will consequently be at the highest voltage or strength when the rotating magnet is in the position indicated in Figs. 7 and 9.

It is also evident that when the rotating magnet is in the position indicated in Figs. 8 and 10, there is no voltage or current on the line, because at that instant there is no magnetism in the soft iron cores, but the moment the rotating magnet is turned slightly, each one of the two poles is nearing its respective stationary iron core, which is thereby magnetized and begins to generate current in the copper magnet coil.

To give an illustration of the flow of current we might assume that when the magnet is in the position shown in Fig. 7 the upper line wire is positive (+) and the lower is negative (—), but when the magnet is in the position as shown in Fig. 9 the upper line wire becomes negative and the lower one positive, and the continued motion of the rotating magnet changes the direction of the flow of the current as many times per minute as the pole piece is rotated past the iron core.

> Electric current can be reduced in a coil of copper wire surrounding a soft iron core by suddenly moving the pole of a magnet past the iron core. The direction of the flow of the current in a coil surrounding a soft iron core depends upon which pole of a magnet is moved past the core.
>
> By rotating a magnet past a soft iron core surrounded by copper wire, successive impulses of current are produced.
>
> The frequency of the reversals depends upon

the speed at which the magnet poles are rotated past the soft iron core.

CYCLES

By modification of the number of rotating magnet poles, and the speed at which they are rotated, almost any desired frequency or number of alternations may be obtained.

It is possible by means of a simple diagram, or curve, to give a representation of the alternating current and

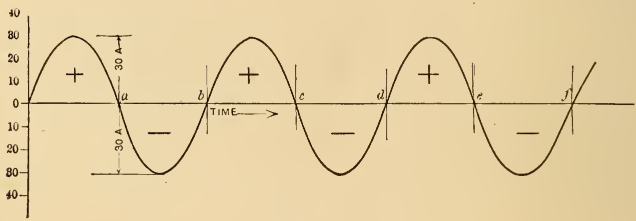


Fig. 11

your attention is called to Fig. 11, in which the horizontal line represents time; the curves above the line represent positive current generated, and the curves below the line represent negative current. The vertical line on the left is a scale of amperes running from zero to 40 above the horizontal line for positive current and below the line for negative current.

Suppose in Fig. 11 the distance from o to f represents one-twentieth of a second. Assume also that we have a 60-cycle alternating current circuit, which would supply a load of 30 amperes. Now we will close the switch at the instant the current is at zero. Following the curve we find the current jumps from zero up to 30 amperes, positive current; then drops to a, continuing downward; then negative to 30 amperes through b; up positive; down through c negative; up through d positive; down through e negative to f. Here we have in one-twentieth of a second made three cycles, or complete reversals, and you will note that there have been three positive impulses of 30 amperes each and three negative impulses of 30 amperes alternately following each other. Also you cannot fail to observe that at the points o, a, b, c, d, e and f, there is absolutely no current generated; neither voltage nor amperes, because at that instant the current changes from one direction to the other.

If we had drawn the time line twenty times longer we would have shown just exactly what happens in a 60-cycle circuit during the period of one second. It would have shown 60 positive impulses and 60 of the negative.

Wherever the curve strikes the horizontal time line, at that instant there is no voltage or current generated, therefore those points represent dead centers, as one might call them, and at those instants if a light is burning it is actually out, but owing to the red hot filament which carries the current, or to the heated carbons of an arc lamp and the vapor of the arc, the glow is maintained, providing the frequency of the current or the number of cycles is sufficiently great to make the change undetectable by the eye.

By this you can understand that the more impulses the current makes in the period of a second the steadier the light will be. That is one reason why with 133 cycles (16,000 alternations) an arc light appears to burn with a steadier glow than at 60 cycles (7,200 alternations) and still more steady than at 30 cycles (3,600 alternations).

It is a fact that it is very difficult to operate arc lamps on circuits of 25 and 30 cycles, because this frequency is very low and the interruptions are quite noticeable to the eye, especially on 25 cycles.

Some years ago, those now interested in the electrical business did not use the terms "frequency and cycles," but the word "alternations" was used to express the rapidity at which the alternating current changed. For instance, in the early days almost all systems were made to deliver 16,000 alternations per minute. Later the systems became 7,200 alternations per minute, and a few power systems were introduced operating at 3,600 alternations per minute.

On account of the many figures representing the number of changes in a minute and the comparatively long space of time of a minute, the electrical profession had, for a long time, used the term "cycle" representing one complete reversal of the current or one positive and one negative impulse. If this occurred 60 times in one second, the circuit was said to deliver a frequency of 60 cycles per second.

I now call your attention to Fig. 12, which represents a copper coil surrounding a soft iron core. This core is under the influence of a rotating magnet with one north and one south pole. The core is revolved by a belt or other means at high speed. Suppose the magnet poles N and S are revolved at a speed of 3,600 revolutions per minute, there being two poles, one north and one south. Then the number of alternations during one minute will be equal to 3,600 multiplied by 2 or 7,200 alternations per minute, which would be correct for the current delivered to the line.

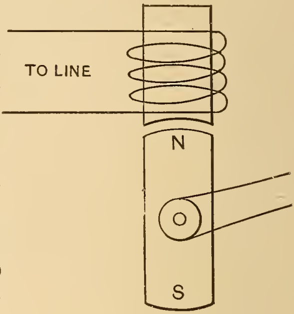


Fig. 12

Suppose, in Fig. 12, that instead of driving the magnet at a speed of 3,600 revolutions it be turned only 1,800 revolutions per minute; then the number of alternations would be 1,800 times 2 or 3,600 alternations per minute.

Let us take 7,200 alternations per minute and reduce this to cycles; first divide 7,200 by 2, which would equal 3,600; then divide this amount by 60 seconds, which gives 60—representing the number of cycles per second.

ALTERNATIONS

To figure the number of alternations delivered per minute by an electric generator, multiply the number of magnet poles on the generator by the speed in revolutions per minute.

CYCLES PER SECOND

When the number of alternations per minute is known, the cycles may be determined by dividing the number of alternations by 2, then dividing the amount obtained by 60.

The alternating current generator is an electric machine in which, by the magnetism from rotating pole pieces, currents are induced in copper coils, surrounding soft iron cores influenced by the rotating magnet poles.

An alternating current electric generator can be made to deliver a certain number of cycles per second with a given number of rotating magnet poles at a fixed speed. If the speed is doubled, the number of cycles per second is also doubled. The number of cycles may also be doubled by increasing the number of rotating poles to twice the number, or the same frequency may be obtained by doubling the number of poles and cutting the speed in two.

THE A.C. GENERATOR

Assuming that you have formed a clear idea of how alternating current is generated in a copper coil surrounding a soft iron core under the influence of a rotating magnet, I will next call your attention to Fig. 13, which is a diagrammatic representation of an alternating current electric generator. The machine is mounted on a base and is composed of a magnet frame, usually made of cast iron, within which are clamped iron cores made of thin sheets of soft iron or special magnetic steel. This soft iron core is so made that copper wire coils can be mounted on projections forming soft iron core pole pieces which do not hold or maintain any magnetism except at the instant one of the rotating magnet poles passes by it.

Upon a main shaft is mounted a pulley and two or more magnet poles which are always magnetically charged when the machine is to generate current.

By means of a pulley or direct connection to an engine or other source of power, the shaft and the magnet poles are rotated at high speed acting magnetically upon the stationary soft iron cores, transmitting alternately north and south pole magnetism to the cores, thereby inducing a current to flow in the copper wire coils, which are connected to the terminals at the top of the generator through which the current generated may be supplied to the switchboard in the power house and then to the line.

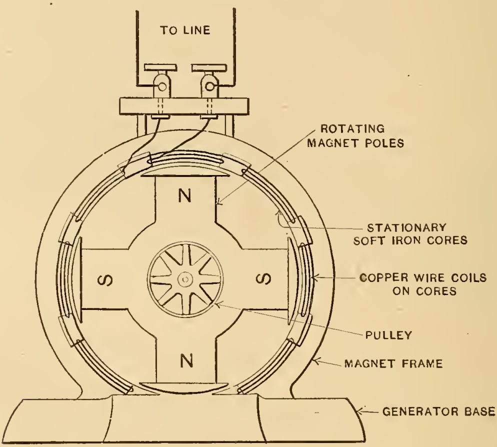


Fig. 13

If the generator illustrated in Fig. 13 operates at the speed of 1,800 revolutions per minute, we find from the rule that we should multiply the speed by the number of rotating pole pieces, which in this case is 4, making the calculation as follows:

1,800 r.p.m. × 4 pole pieces = 7,200 alternations per minute. If we wish to reduce this figure to cycles divide 7,200 by 2, which equals 3,600, and divide this by 60 seconds, equals 60 cycles.

In making the diagrammatical sketch, Fig. 13, I have not attempted to make an actual representation of a generator, but one which would plainly illustrate the different parts of the generator and their functions. You can understand, of course, that there may be any number of pole-pieces and the design may be changed to suit the particular ideas of the designer.

It has been stated that the current leaves the generator at the terminals and is transmitted through highly insulated cables to the switchboard. I wish to call your attention to the fact that alternating currents are usually generated at voltages varying from 1,000 up to 6,600 volts, and you can understand that on account of the high voltage windings being stationary, therefore not subject to excessive vibration and also on account of having more room than on an ordinary rotating armature, it is possible to put on a greater quantity of insulation on the copper wire, which forms the magnet coils, and there is also plenty of room for insulation between the coils and the soft iron cores, permitting the high voltage above mentioned to be generated and sent to the switchboard without any danger either to the man who handles the machine or to the machine itself.

I have illustrated the rotating magnet poles without complication and you may imagine that the poles are made from hardened steel magnetized so as to form permanent magnets. In practice, however, it has been found to be more economical and preferable to put a copper coil on each one of the rotating magnet poles. The coils are connected in series and the two terminals are then connected to two "Collector Rings"—mounted on the shaft which rotates with it. Two copper gauze or carbon brushes rest one on each collector ring and direct current from a storage battery or from a small direct-current generator usually called the "exciter" is supplied to the brushes, allowing the direct current to flow from the collector rings, through the magnet coils on the rotating poles, which are thereby magnetized to any desired extent under the control of the dynamo attendant who can increase or decrease, by means of a field rheostat, the voltage and current delivered by the "exciter."

Fig. 14 illustrates the rotating magnet and collector rings, when the field magnets are excited by magnet coils through which direct current is flowing from a small direct-current generator.

Large alternating current generators are usually made with a number of rotating magnet poles, alternately of north and south pole magnetism.

On account of the difficulty of securing a permanent magnet of large size and also on account of the impossibility of regulating the strength of the magnetism from a permanent magnet; the pole

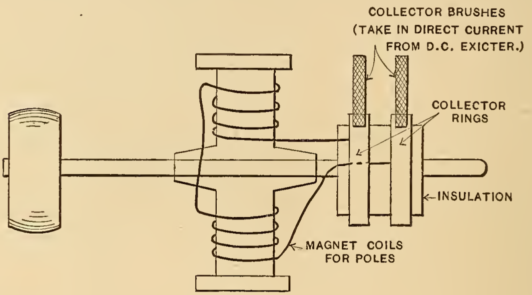


Fig. 14

pieces of an alternating-current generator are usually magnetized by copper coils, through which direct current flows.

The magnet poles of an alternating-current generator have to be supplied with direct current, which is usually furnished by a very small direct-current dynamo or generator, which is provided with its own field rheostat by means of which the attendant in the power house can increase or decrease the voltage of the small generator, or "exciter," thereby increasing or decreasing the current flowing in the magnet coils on the magnet poles of the larger alternator, which in turn increases or decreases the voltage of the alternating current delivered by the alternating-current generator.

CHAPTER III

The Transformer for Alternating Current

THE electric transformer is a device for producing a current of different quantity and potential than the supply current. In alternating-current lighting or power systems, the transformer reduces the primary line voltage to a lower voltage suitable for the interior of buildings, in which case it is called a "step-down" transformer. In some instances it is desirable, when transmitting electric energy, to generate the current at a low voltage, then for long distances where high voltage is required on the line wire, a transformer is introduced between the generator and the line wires for increasing the line voltage, in which case it is called a "step-up" transformer.

CONSTANT POTENTIAL TRANSFORMER

For general requirements, however, we need only consider the step-down transformer, which consists of several parts, which are diagrammatically illustrated in Figs. 15, 16, 17, 18 and 19.

There are several types of transformers, some intended to reduce from one voltage to another main-

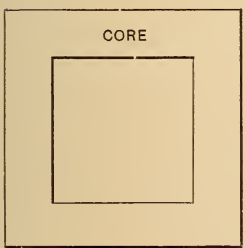


Fig. 15

Fig. 16

taining the voltage delivered as nearly constant as possible, irrespective of the load. This type of transformer is called "constant potential."

For other purposes transformers are required to reduce a given line voltage to a steady flow of amperes as may be required for a motion picture arc lamp or for operating arc lamps in series, as is usually done for street lighting, and this kind of transformer is said to be of the "constant current" type, because it maintains a steady ampere flow on the circuit which supplies the arc lamp, or in case of street lighting several arc lamps in series.

For the present, we will only consider the step-down constant potential transformer, and referring to Fig. 15, the illustration gives a top view of the core, and Fig. 16 gives an end view of the core.

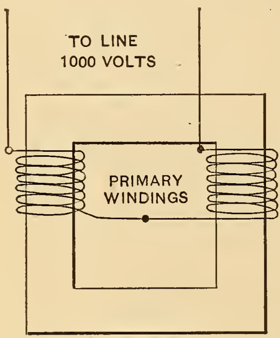


Fig. 17

The core of an alternating current transformer is made up of sheets of annealed iron, or specially prepared electrical steel. The sheets must be very thin; not more than 1-64 of an inch. The best transformers use sheets not over 1-100 of an inch thick. In constructing the core it is also necessary to provide a thin layer of insulation between every sheet of iron, and this is usually accomplished by painting one side of the iron with some insulating compound. These sheets of iron are usually called "laminations," and a core made up from such sheets is called "laminated core." After the sheets have been stacked on top of each other to the desired thickness, which is determined by the size of the transformer, they are insulated by fiber, press board and mica, so that the copper coils may be placed around the core legs without any danger of touching the iron.

Fig. 17 illustrates the core, with the primary or high voltage winding in place. This winding is generally composed of a comparatively great number of turns of small insulated copper wire in the shape of coils surrounding the core legs. For argument sake, we might assume that this transformer has 1,000 turns of copper wire for the primary winding and that the line voltage is 1,000.

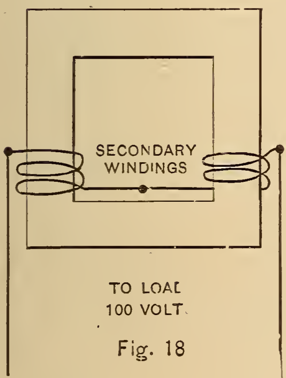


Fig. 18

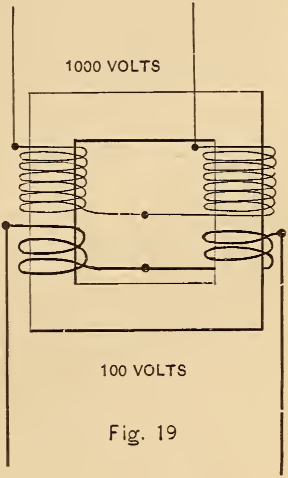


Fig. 19

Referring to Fig. 18, you see the secondary winding of this same transformer mounted on the core legs. This winding is composed of comparatively few turns of larger insulated copper wire, and we may assume in this instance the two secondary coils are composed of 100 turns, which if connected to the load will deliver about 100 volts.

Fig. 19 shows the complete transformer with laminated core, primary and secondary windings in place, making a complete transformer wound for 1,000-volt primary, and 100-volt secondary to be used as a "step-down" transformer.

This same transformer illustrated in Fig. 19 can be used as a "step-up" transformer by connecting the 100-volt line to its secondary 100-volt windings, in which case they become primary and this transformer will deliver on its secondary 1,000 volts, so that you can see that *the same transformer can be used for "step-up" or "step-down" work.*

The operation of the transformer is as follows: When the alternating current passes through the primary winding it produces magnetism in the iron core, which is reversed 60 times per second on a 60-cycle circuit. This magnetism, in turn, induces electric current in the secondary windings and the voltage of this current will depend upon the number of turns of wire on the core. I have illustrated how the primary is wound with 1,000 turns of wire for 1,000 volts, and the secondary with 100 turns of wire for 100 volts. It is evident that this ratio which, in the above case, is 10 to 1, can be changed to any desired amount by putting more or less turns of wire on the primary and secondary coils.

The transformer, for alternating current, is a most efficient and useful device. In fact, it has made the alternating current of great value, because it permits generating and transmitting high voltage currents of great power at low amperage over small wires to be reduced efficiently and with safety to low voltage currents and great power of higher amperage as is required for lighting, power and heat.

> The transformer when reducing a high voltage is called "step-down" transformer; when increasing the voltage, it is called "step-up" transformer.
>
> The transformer has three distinct parts: The laminated iron core, the primary winding and the secondary winding.
>
> The number of turns of the primary and secondary windings determine the ratio of transformation.

"Constant Potential" means steady or constant voltage and when used in connection with a transformer it signifies that a change in voltage is required and that the delivered voltage must be maintained constant, or steady, irrespective of the load. A constant potential transformer is the type required for electric power, incandescent lamps and constant potential arc lamps such as are usually employed in factories, stores and theaters.

It is not an easy matter to design and construct a transformer which will regulate well, that is, hold the voltage steady, whether one lamp or the entire number of lamps connected are burning. If the transformer does not regulate well, the voltage will be high when only a few lamps are burning and as more lamps or motors are switched on, the voltage will drop lower and lower. Modern transformers are constructed to give a practically constant voltage irrespective of the load, and the regulating quality of a constant potential transformer depends mainly upon the amount of magnetic leakage.

CONSTANT CURRENT TRANSFORMER

If the magnetic leakage is great the transformer will not regulate well and the voltage will drop more and more as additional load is put on.

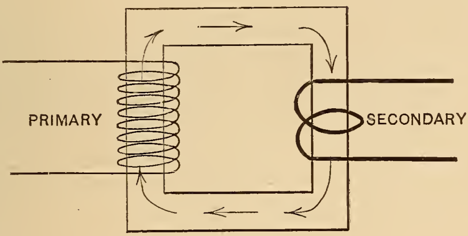


Fig. 20

Fig. 20 illustrates a transformer having considerable magnetic leakage because the primary and secondary coils are some distance apart and are mounted on separate legs of the iron core. When the line current passes through the primary coil it generates magnetism in the iron core and the current being alternating this magnetism is reversed a given number of times per second, depending upon the frequency of the current. If the secondary coil is not connected to any load, the magnetism will pass through the iron as indicated by the arrows, first in one direction, then when the current reverses in the other direction performing no work, simply keeping the iron core "excited," and the secondary coil under tension.

If we should now put load on the secondary coil as indicated by the arc lamp in Fig. 21, all of the magnetism will no longer pass through the core leg upon which the secondary coil is mounted, but some of the magnetic lines of force will crowd over the air gap between the primary

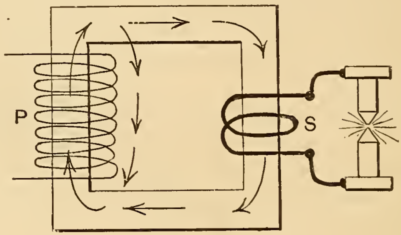


Fig. 21

and secondary coils and these lines are therefore lost and are of no use in producing voltage in the secondary coil, allowing the voltage in the secondary to drop when the arc lamp is turned on.

Therefore, you can understand that a transformer built as illustrated in Figs. 20 and 21 is a very poor constant potential transformer, in fact it would not do at all, unless a given number of lamps were always burning at the same time, because the voltage would fluctuate up and down as the number of lamps were decreased or increased.

CONSTANT POTENTIAL WINDINGS

In view of the foregoing it becomes necessary to place the primary and secondary coils of a constant potential transformer very close together and, as a matter of fact, modern transformers are built in sections with the primary and secondary windings sandwiched between each other and in some instances the windings are one on top of the other as illustrated in Figs. 22 and 23, in order to minimize the magnetic leakage.

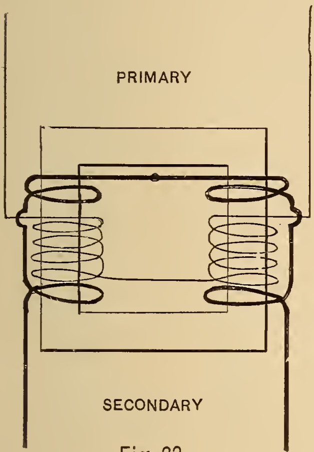


Fig. 22

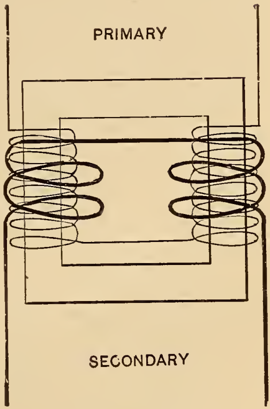


Fig. 23

The core for a transformer may be of many different shapes. The type which has been previously illustrated is called the "core type," having two magnetic legs.

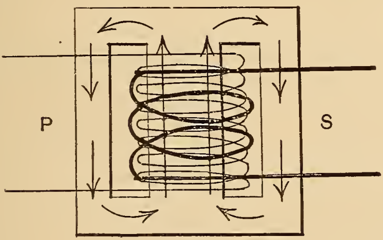


Fig. 24

Fig. 24 illustrates another type also much used, which is called the "shell type" transformer. In this design there are three legs, the middle one is usually of double the cross-section as compared with the two outside legs and the primary and secondary coils are mounted on the middle leg as illustrated.

Either the core type or shell type transformer gives satisfactory results and there are certain advantages claimed for both types. As a matter of fact as far as efficiency and regulation is concerned there is not much choice and either one may be used with safety and satisfactory results. The determining factor in making a selection of the two being simply a matter of choice with the designer.

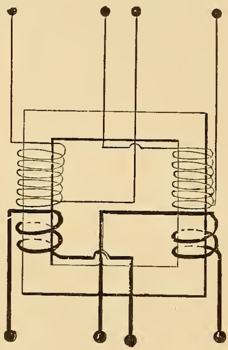


Fig. 25

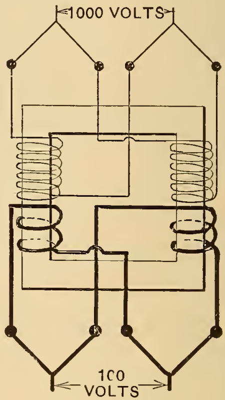


Fig. 26

The constant potential transformer must have the lowest possible amount of magnetic leakage in order to maintain the voltage constant irrespective of the amount of load on its secondary.

In order to reduce the amount of magnetic leakage, the primary and secondary coils of a Constant Potential transformer should be mounted very close together or one on top of the other on the same core leg.

All modern constant potential transformers are usually made with two primary and two secondary coils, each coil having its terminals brought outside of the transformer case, permitting the primary coils and secondary coils to be connected in series or parallel as may be required for different voltages and for either 2-wire or 3-wire system.

Fig. 25 shows the four primary and four secondary terminals. Suppose each primary coil is wound for 1,000 volts and each secondary coil for 100 volts, then if the connections are made as illustrated in Fig. 26, the transformer may be operated on 1,000-volt line to deliver 100 volts on the secondary, because the primary and secondary coils are now connected in parallel.

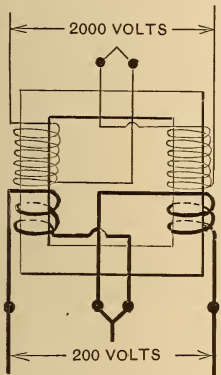


Fig. 27

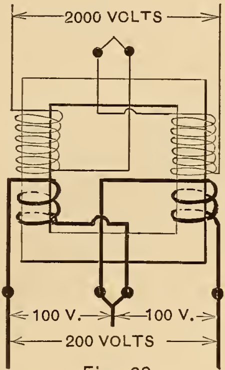


Fig. 28

If the connections be made as illustrated in Fig. 27, then the coils being connected in series, the transformer would be adapted for operation on 2,000-volt line and to deliver 200 volts on the secondary. It is evident that by connecting the secondary as shown in Fig. 26 and the primary as shown in Fig. 27, you would have a transformer adapted to operate on 2,000-volt primary to deliver 100 volts on the secondary because the primary coils are in series and the secondary coils in parallel.

Now we may go one step further and your attention is called to Fig. 28, in which you find the two secondary coils connected in series, but the middle wire brought out from the transformer, in which case the transformer would operate on 2,000-volt line and on the secondary there would be available 100 volts between each of the outside wires and the "neutral" or middle wire and 200 volts between the two outside wires.

The foregoing illustrations represent correctly the following:

Fig. 26, the 2-wire 100-volt system.
Fig. 27, the 2-wire 200-volt system.
Fig. 28, the 3-wire 100 and 200-volt system.

Throughout the country there are many different systems of distribution in use, and of these the three-wire system is perhaps the most complex and requires more care and judgment in its handling and installation. Referring to Fig. 28 you have therewith illustrated a transformer reducing from a 2,000-volt line to 3-wire 100 and 200-volt secondary. This transformer is usually mounted on a pole outside of the building where the primary wires are connected through two protecting fuses (usually mounted on the pole cross arm or made a part of the transformer itself) to the line wires. The three secondary terminals are then connected to the feed wires which go into the building, in fact in some instances the electric lighting company may place one transformer in the middle of a block where it is connected to the line wires, then the company will run three large wires along the block to which the three secondary terminals from the transformer are connected, thus feeding the three main wires running along the street with current at 100 to 110 volts between the "neutral" or middle, and each outside wire, and 200 to 220 volts between the two outside wires. Where one transformer is installed for the service of a whole block or for several adjoining buildings it is evident that upon the regulation of this one transformer depends the constancy of the candle-power of all lamps connected to that particular transformer. It is the aim of all manufacturers of transformers to make the regulation as close as possible so that the voltage will be the same, irrespective of the number of lamps burning and the manufacturers have been very successful in accomplishing these results.

It is a very difficult problem to build one transformer with two secondary windings connected to a three-wire system as illustrated in Fig. 28, which will maintain the same voltage on either side of the neutral wire irrespective of the number of lamps burning and the nature of the load represented by incandescent lamps, arc lamps, motors, etc. The 3-wire system as illustrated in Fig. 28 under normal conditions is a balanced system, that is, if the voltage between the outside wires is 200 the voltage between the neutral and each outside will be 100. Suppose we connect a motion picture arc lamp between the neutral and one outside wire and there are no other lamps on the opposite side of the system or at least only a comparatively small number of lamps, the side on which the motion picture lamp is connected may allow the voltage to drop to 90, but at the same time the voltage on the opposite side will go up to 110. This, of course, makes a fluctuation in the candle-power of the lamps and besides it makes the motion picture lamp burn dimmer than it ought to.

You realize that if this same transformer feeds a number of lamps in neighboring shops and establishments a big kick will be registered with the electric lighting company, due to the voltage fluctuation and consequent increase and decrease of candle-power of their lamps. This problem involves a careful system of balancing the load between the neutral and each outside wire of the 3-wire system and it also requires a carefully designed and constructed transformer. This is one reason why it is always well to consult the electric lighting company's expert or other competent authority when laying out the electric installation, especially when the 3-wire system is used.

All modern transformers are made with two primary and two secondary coils, the terminals of all coils being so arranged that the primary and secondary may be connected for either series or parallel operation, which permits the same transformer to operate on two different voltages on both primary and secondary for either 2-wire or 3-wire system.

When the 3-wire system of electric distribution is employed great care should be exercised in balancing the load properly between the neutral and the outside wires so that the unbalancing of the voltage and consequent change in candle-power of the electric lamps will be reduced to a minimum.

CHAPTER IV

Electrical Service

IN the previous chapter careful discussion has been given to the fundamental rules governing the generating and distributing of electricity. I have purposely avoided reference in particular or detail to the electric installation on the premises of the consumer of the electric current, limiting previous discussions to general information on how the electric light company generates and distributes electricity to be used by the consumer.

STREET SERVICE

Fig. 29 is a plan view of a street showing part of a few regular building blocks. You will observe that the stores along the street are of different sizes, requiring a greater or less number of lamps, and the electric lighting company has located its poles and wires on one side of the street. The section is intended to illustrate one or two business blocks where considerable electric current would be required.

For the sake of simplicity I omit showing the high voltage wires, illustrating only the secondary wires from the transformer or the low tension wires of a regular 2-wire and 3-wire direct-current system. In the illustration the transformer mounted on top of one of the poles receives current from the high voltage system over two small wires, and this transformer feeds 2-wire or 3-wire main running along the street as illustrated. Suppose the electric light company gets a customer for store A and they require only eight or ten 16-candle-power incandescent lamps, which would require approximately 5 amperes at 110 volts. In this case it would not be necessary to bring all three wires into the building, so only two

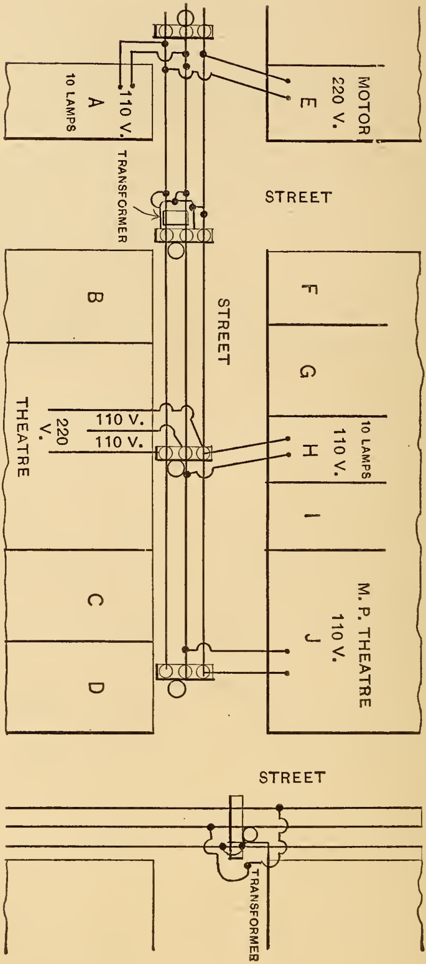

MOTOR
220 V.
E
10 LAMPS
A
110 V.
TRANSFORMER
STREET
B
F
G
STREET
110 V.
110 V.
220 V.
THEATRE
10 LAMPS
110 V.
H
I
C
M. P. THEATRE
110 V.
J
D
STREET
TRANSFORMER

Fig. 29

wires are brought in: namely, one of the outside and the "neutral" wire, as illustrated. This will serve the customer with 110-volt current.

Suppose a customer at E is running a factory where he wants a large electric motor installed, but he does not require any light, then the electric company would furnish him with current at 220 volts, in which case they would bring in the two outside wires of the system as illustrated. Suppose the theater in the center of the block wants current for incandescent lighting, ventilating, spot lights and motion pictures and stereopticon lights. In this case the electric company would bring in all of the wires, giving to the theater the regular 3-wire system, which delivers 110 volts on each side of the "neutral" and 220 volts between the outside wires.

A new customer wants current at H for about ten incandescent lamps, then the electric company will run across the street with only two wires, giving 110 volts.

If you closely study Fig. 29 you will find that this 3-wire system is balanced because there are ten lamps in store A at one side of the 3-wire system which are balanced against ten lamps in store H on the opposite side of the system. The motor is on the two outside wires getting 220 volts in Factory E, which, of course, does not unbalance the system and the theater having all three wires brought in will give a balanced load to the system, providing the wiring and the arrangement of the lamps, motors, etc., is properly attended to by a competent electrical man.

Suppose a motion picture theater starting at J requires electrical service for a motion picture lamp and a few incandescent lamps and that the building J has been wired for 2-wire system, the electric light company will be compelled to run only two wires to the building unless it is re-wired and the choice is one of the outside wires and the "neutral," in which case 110 volts is supplied, or the two outside wires which would deliver 220 volts. The motion picture man's machine, motors and fittings happen to be made for 110 volts there is only one choice and that is, the 110-volt service.

Suppose the system is alternating and the rheostat is used, then for a good light two rheostats must be used in parallel or multiple. The motion picture lamp would draw around 60 to 70 amperes the instant the carbon points are put together and would normally require around 45 amperes. You can imagine how the previously balanced 3-wire system referred to and illustrated in Fig. 29 would be disturbed every time the motion picture at J is switched on and put in operation or when it is cut off.

The result in practice would usually be that all customers connected on the same side of the 3-wire system as J would notice a considerable drop in the candle-power of their lamps, as would be the case in store H, and there would be a drop in candle-power of all lamps connected to the left-hand 110-volt circuit brought into the theater on the opposite side of the street. On the other hand, the lamps in store A would burn brighter, as would also the lamps connected to the right-hand side of the electric service for the theater.

This unbalancing has already been referred to in previous chapters, but I want you to keep in mind the serious inconvenience and disturbance to an electric system which has been subjected to unbalancing of the load. To operators of motion picture machines this point is of particular importance, because if the voltage drops below normal, the operator cannot produce results, and just because you always had good current, that is no reason why tomorrow the condition may not be changed, possibly due to one of your neighbors putting in a motor or additional lamps, and these may be connected to the same side of the system to which your motion picture lamp is connected, forcing the voltage below normal.

I know of some instances where electric service has been run into a theater and everything appeared to be satisfactory for a long time. Suddenly the motion picture lamp would not work properly, nor would the outside arc lights, and the manager observed a considerable dip in the candle-power of his incandescent lamps every time the motion picture lamp was switched on. Upon investigation it was found that the electric lighting company's linemen had connected another customer to the same wires and transformer which supplied the motion picture theater, overloading the wires and the transformer, and the most natural thing in the world followed; namely, a big drop in voltage, and consequently in the light, as less amperes can be put through the lamps with the lower voltage. Dissatisfaction follows, and the operator is unjustly blamed, in many instances, for troubles caused by interference in the electric system beyond his control. It really takes a voltmeter to tell whether the voltage is right or wrong and to what extent the voltage may drop, but an expert can also judge approximately the voltage drop by the dip in the candle-power of incandescent lamps connected to the system.

> With a given system of electric mains running in front of a number of buildings, whether 2-wire or 3-wire system, perfect results can be had if the voltage supplied to the mains is constant, the mains are of proper size, the transformer of proper size, and the load properly balanced between the "neutral" and each outside wire.
>
> With a system as that described above, great troubles may be experienced if the voltage varies, if the wires are too small, if the transformer is too small, or does not regulate well, and if additional load is added without consideration being given to the proper balancing of the load and the necessary increase in size of transformer, mains, service wires, electric meter, switches and fuses.

I have referred to an installation for a motion picture theater in building J, of Fig. 29. By referring to it you will see that the load for this theater consists of the motion picture lamp and a number of incandescent lamps, which had to be connected for 110 volts, and that in order to give this voltage, the electric light company had to use the neutral and one outside wire of the 3-wire system, and we also found that the system became unbalanced on account of this installation, which is, of course, undesirable, for reasons which have already been explained. The inconvenience, from variations in the voltage, not only affects the operator in the motion picture theater, as his light is likely to be poor, but it also affects other consumers supplied from the same system. In many instances the electric light companies find it convenient to make such a connection, because it has to be made in a hurry, or they do not anticipate difficulties which might arise therefrom. A much better way would have been to supply the theater J with current from a separate transformer; the primary of which could be connected to the high voltage primary line wires, and the 110-volt secondary transformer wires could then be connected to the 2-wire service. This would overcome all trouble, and there would then be no voltage drop due to unbalanced load on account of the motion picture lamp in theater J. It is the aim of all electric lighting companies under modern management to avoid the unbalancing of a 3-wire system by putting in separate transformers and service for customers who have a load of such nature that it is likely to unbalance the system, but sometimes it becomes necessary for the manager or the operator of the motion picture theater to register a complaint about the drop in voltage when the motion picture lamp is switched on and the consequent rise in voltage when the lamp is switched off, and the sooner the electric light company is made aware of this voltage variation, and corrects it, the better for all concerned.

INTERIOR SERVICE

After proper mains have been brought into a building for the supply of electric current, a service switch with fuses of proper capacity must be installed as close to the entrance of the wires as convenient. The purpose of this switch is to disconnect entirely the electric current supply from the building at night, so as to insure perfect safety and also give the proprietor absolute insurance that no lamp is burning which would cause the meter to register unexpectedly and unnecessarily.

The electric lighting company will then install an electric meter of proper size, and the wires from the meter may then be run to an electric distribution panel, which must contain the necessary fuses and switches for the protection of the various groups of lamps, fans, motion

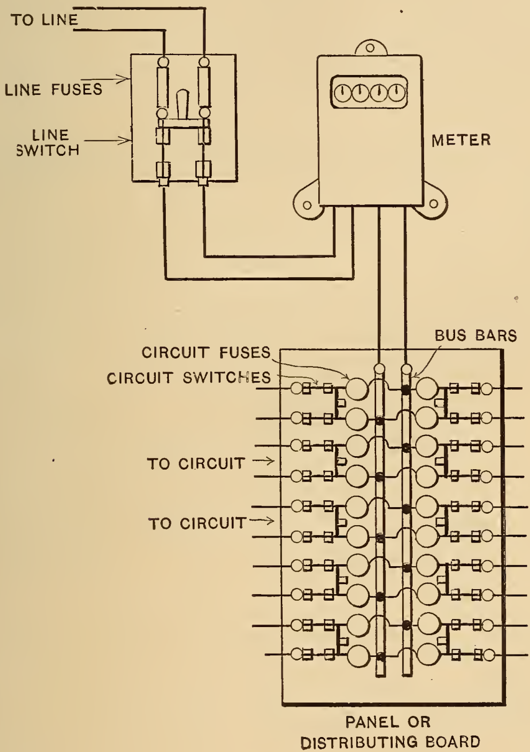


Fig. 30

picture machines, flaming arc lamps, spot lights, etc. The panel board referred to is usually located at a convenient point where the manager or other person in charge has full control of every circuit, permitting the turning on and off of the various circuits, and the fuses should be of proper capacity to protect the wires connected to the switches.

The term "panel board" usually signifies a small switch board made of slate, upon which are mounted bus-bars, or copper strips, to which the mains are connected, including also the proper number and size of switches and fuses which are connected to the bus-bars. The various circuits are then connected to the switches.

Two-Wire Service.—Fig. 30 is a diagram illustrating a typical two-wire installation, including the following:

Line fuses. Line switch.
Meter. Panel board for ten circuits.

It is evident that in place of the panel illustrated, a cheaper form of distributing board can be constructed. For instance, in place of the board illustrated, there could

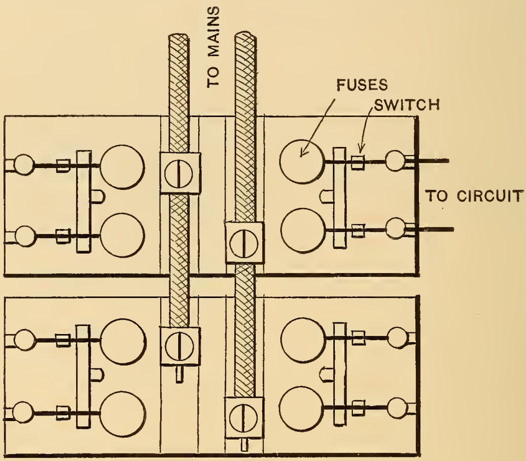


Fig. 31

be used a number of double-pole, double-branch, combined cut-outs and switches mounted on the usual form of porcelain base as illustrated in Fig. 31. Wherever panel boards or cut-outs are installed, they should be mounted in a suitable box, which should be made preferably of slate, or it should be lined with sheet iron and provided with a door lined with the same material, so as to make a practically fireproof cabinet, and the door should be provided with a lock, so that outsiders may not have opportunity to interfere with the fuses or switches. No panel box is complete without at least one extra fuse for each circuit; to be on hand in case of an emergency.

A panel board should always be examined at frequent intervals to make sure that all connections are tight, also to make sure that the fuse plugs, or any other form of fuse that are used, make good and perfect contact. The switches should occasionally be examined to see that the clips make good contact with the switch blade. A little vaseline or flaked graphite applied to the clips will prove advantageous and will increase the life of the switch, also insuring better operation.

Attention to these small details will often prevent trouble, and there is one thing you should remember; that is, that a loose contact or an overloaded wire, fuse or other connection always costs money, because a loose contact or a small wire generates heat, and as this heat requires electric energy, it represents a useless expense, besides a loose contact will also lower the voltage to such an extent as to interfere with the proper operation of your installation.

Electric service within a building must be amply protected by proper fuses and switches, and a suitable distribution panel should be located at a convenient point giving full control of all circuits within the building.

Frequent examination should be made of all contacts, fuses, and switches to insure minimum loss and to improve the operation of the lamps and apparatus connected to the system.

Three-Wire Service requires the usual protecting, metering, and distributing devices—the same as for 2-wire service, but in somewhat modified form, because of the fact that the 3-wire system has a third or "neutral" wire between the two outside wires, and instead of delivering only one voltage it is possible to get two different voltages from a 3-wire system, which is often of advantage, and besides, it makes it possible to carry a heavier load with smaller wires, switches, fuses, etc.

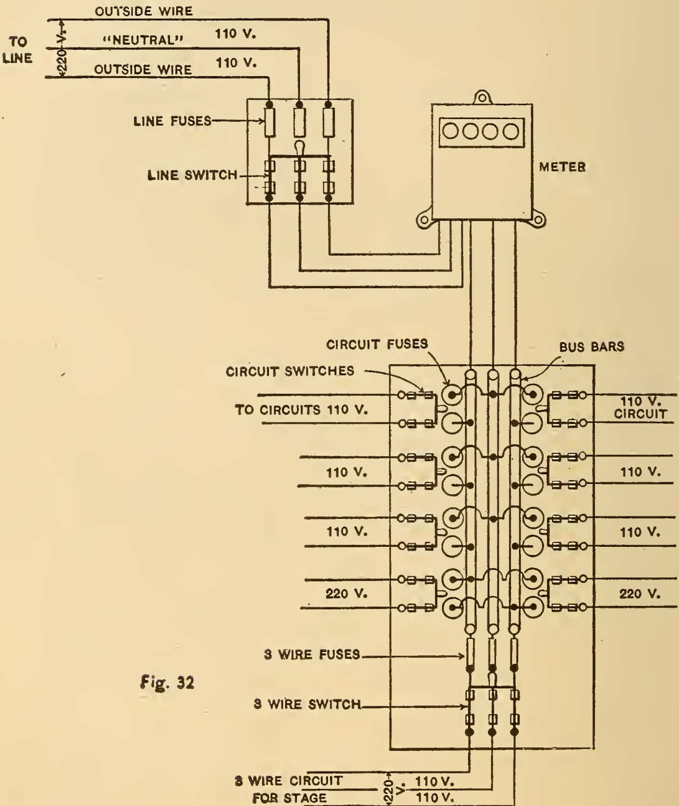


Fig. 32

Fig. 32 is a diagram illustrating a typical 3-wire installation, including the following:

Three-line fuses. Three-pole line switch.
Meter. Three-wire panel board.

The line fuses are connected to the 3-wire lines coming into the building. On the outside wires, there is usually a pressure of 220 volts and between the "neutral" or center wire and either one of the outside wires the voltage would then be 110. The wires leave the switch and go into the meter. From the meter three wires are run to the distributing panel board, which is clearly illustrated in Fig. 32. You will note that the three top circuits on each side of the bus-bars deliver 110 volts, because they are connected to the middle and one of the outside bus-bars alternately. The two lower switches, however, are connected to the outside bus-bars only, therefore the voltage available on the two lower circuits is 220 as may be desired for large ventilating motors, motion picture and stereopticon lamps or for spot lights operating on electric economizers. At the bottom of the panel board there is illustrated an additional set of three-pole fuses and a three-pole switch for a three-wire circuit as may be required for a separate section of a building, for instance; in a theater the panel board may be in the front of the house where the electric company's service enters, and from this point all of the local circuits are controlled, but for the stage lighting a separate three-wire circuit may then be run to the stage to feed the panel board for the various stage circuits, auditorium lights, etc., which must necessarily be under the control of the stage electrician. This arrangement gives regular three-wire service for the stage practically independent of the other lighting circuits and gives also either 110 or 220-volt current for the stage as may be required for various types of appliances and lamps used for stage work.

Fig. 33 illustrates a more simple form of three-wire distributing board made up of standard two-wire or three-wire cut-outs with switches and fuses mounted on the regular porcelain base. These may be mounted in a suitable cabinet lined with slate or sheet iron, as already described, for the two-wire system giving perfect protection and control of the various circuits.

Note that in Fig. 33, for convenience sake, I have placed the three-wire branch circuit, switch and fuses at the top as may be required for a small stage circuit. Below is mounted three-wire to two-wire cut-outs delivering 110 volts to each circuit and at the bottom there is a two-wire double branch cut-out connected to the two outside wires only, therefore giving 220 volts to each cir-

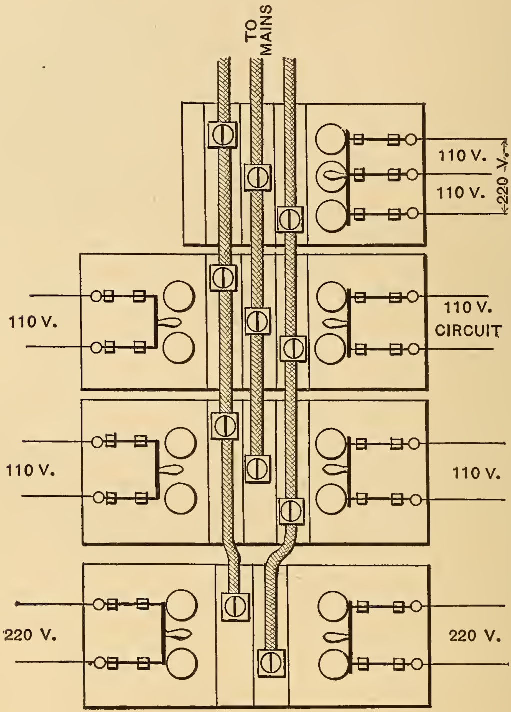


Fig. 33

cuit. Any number of cut-outs of any desired type can be added or arranged in any suitable manner for giving 110 or 220 for either two-wire or three-wire circuits.

Whenever three-wire service is used, it becomes important to the operator and the electrician within the building to balance the load on either side of the system as perfectly as possible, the same as the electric light company must do it outside of the building. In fact, you should be even more particular about the balancing within the building because of the fact that your service is smaller and an unbalanced condition within the building is more likely to give trouble than unbalancing outside of the building. The balancing of the interior lighting is, of course, difficult to accomplish if a large unit like a motion picture arc lamp is connected to one side of the system to operate on 110 volts. Therefore it is always desirable to connect the motion picture lamp, stereopticon and spot lights to the outside 220-volt wires as illustrated in Fig. 33 at the lowest cut-out. In that case it should be understood that when 220 volts is used and a rheostat is employed for the control of such lamps, the load is twice as great as it would be with 110 volts, but the "balance" of the system is maintained perfectly, and by the use of an electric economizer the extra loss can be entirely done away with, thus maintaining the "balance" of the system.

> The three-wire service within a building requires careful balancing of the load, giving an equal number of amperes on either side of the three-wire system.
>
> When motion picture, stereopticon, or spot lights, are operated on a three-wire system, it is better to connect such lamps on the outside or 220-volt wires.

THE RECORDING WATT-HOUR METER

When electricity was first offered for sale, the electric lighting companies generally made a contract with the consumer to supply him with current to operate a given number of lamps, motors or other devices. This flat rate allowed the consumer to use the lamps or devices as long as the current was maintained at his service. Such an arrangement or contract was unjust to all concerned, and after a few years the electric lighting companies found that it was absolutely necessary to secure some means for measuring the exact amount of current required by each consumer and charge him therefor in accordance with the reading of the meter.

A consumer, in the early days, may have had one hundred 16-candle-power lamps in his store divided on two or three floors. According to the old system he would be obliged to pay, we will say, for argument sake, $1.00 for each connected 16-c.p. lamp per month. This would make his monthly bill $100, no matter how long or how many of the lamps installed were burning.

The first step taken by the electric lighting companies was to secure means for determining just how many of the lamps installed were burning a given number of hours, and those figures were obtained by watching the installation, in some instances secretly, to see just how many lamps were burning on the average. An ordinary indicating ampere meter was connected on the premises of the consumer and an expert was stationed there to take readings, many times a day and night, thus establishing an average figure for the consumption. Should the consumer add a few lamps or a fan motor to his installation or burn his lamps longer than usual or than contracted for, the electric lighting company would be the loser. On the other hand, should the consumer, as is the case during the light months of the year, burn his lamps a lesser number of hours, he would be the loser.

These difficulties forced the electric lighting companies to demand from the electric manufacturers some form of electric meter, and as a result the recording ampere hour meter was offered for sale and installed in many instances by the electric companies.

The recording ampere hour meter served its purpose twenty years or so ago, inasmuch as it registered on a number of dials the number of ampere hours used by the consumer and who was charged in accordance therewith. As long as the voltage on the electric company's system was maintained constant, and the load consisted of incandescent lamps or other non-inductive load only, the recording ampere hour meter gave good satisfaction.

Not many years after the introduction of the recording ampere hour meter, the manufacturers developed what is now known as the Recording Watt Hour Meter.

The recording watt hour meter gives the instantaneous value of the watts expended in the circuit, and is, as its name indicates, a recording watt hour meter, and its reading gives the product of the watts and time, i. e., the watt hours. The construction is simple, the principle is, broadly, that of the Siemens Dynamo-Meter, which is composed of a stationary coil of copper wire in series with the load and surrounding this coil there is suspended another at right angles to the first coil and this outside coil is connected in shunt with the load, as illustrated in Fig. 34. In the recording watt hour meter, however,

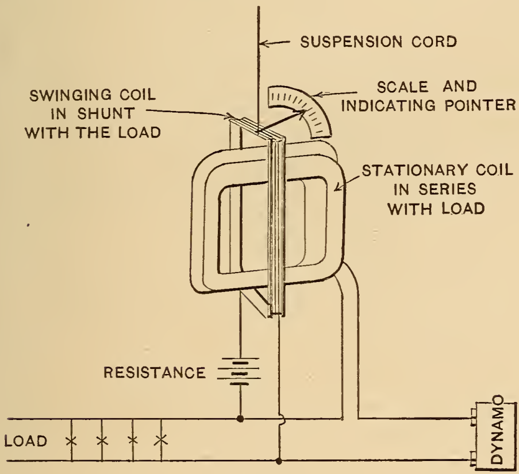


Fig. 34

the movable coil is not held to zero position, but revolves between two fixed coils. The movable coil is really a small drum-wound armature provided with a small commutator made of silver to prevent oxidization. The effect of using the commutator is to make the effective plane of the moving coil (armature) take a position at right angle to the plane of the fixed coils.

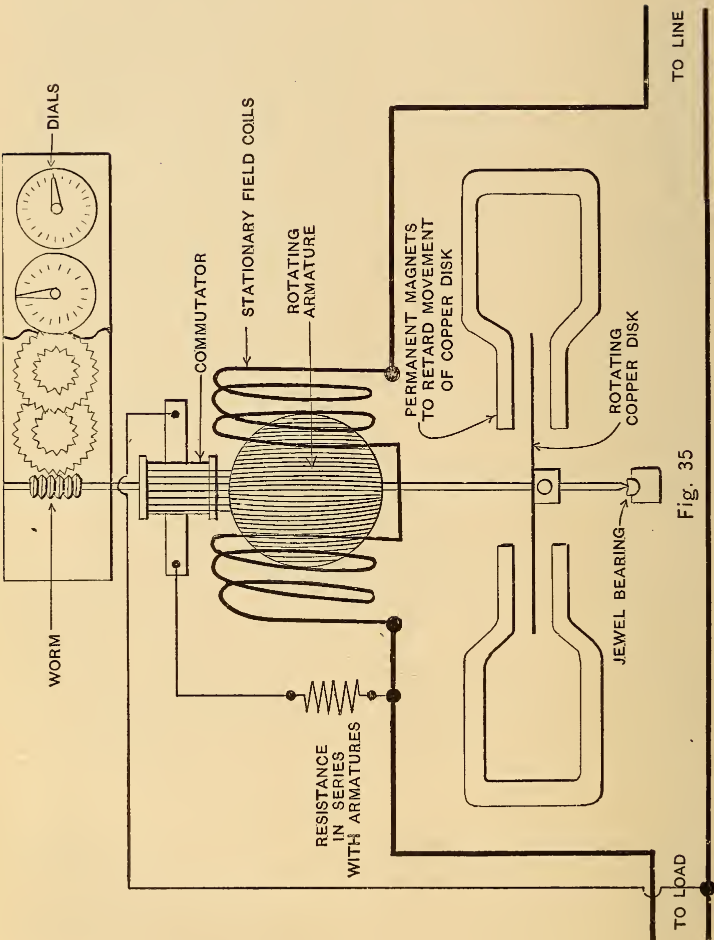

DIALS
WORM
COMMUTATOR
STATIONARY FIELD COILS
ROTATING ARMATURE
PERMANENT MAGNETS TO RETARD MOVEMENT OF COPPER DISK
ROTATING COPPER DISK
JEWEL BEARING
RESISTANCE IN SERIES WITH ARMATURES
TO LINE
TO LOAD

Fig. 35

The connections of the recording watt hour meter are made on the same principle as those of the indicating watt meter illustrated in Fig. 34. The fixed coils are in series with the circuit and the movable coil and a small resistance in series with it are in parallel with the circuit as illustrated in Fig. 35.

The amount of energy expended in the circuit is measured by the rotation of the movable coil or armature, which rotates and drives a worm on the upper end of the armature shaft engaging with a set of gears which operate a dial similar to a gas meter dial so that the energy expended in a given time in a circuit may be read directly from the dial in watt hours.

The friction of the apparatus being exceedingly small the retarding force on the coil that opposes its tendency to rotate is imparted by a thin copper disk attached to the lower end of the shaft on which the armature is mounted. This disk is rotated between the poles of strong permanent magnets; the lines of force from the magnets cutting the disk, set up electro motive forces between adjacent points on the disk; the disk being of copper, the resistance between those points is very low, so that a considerable local current may flow in the copper disk. This current tends to retard the rotation of the copper disk, and this tendency increases directly as the speed. The force acting to rotate the armature increases directly as the watts, therefore, the number of revolutions of the moving system of the meter will be directly proportional to the watts expended in the circuit. This type of meter may be used for either alternating or direct currents, and gives very accurate results.

The indicating watt meter is an instrument which, while applied to a circuit will indicate or show while it is under observation, the number of watts expended at a given instant in an electric circuit.

The recording watt meter is an instrument which records the number of watt hours expended in an electric circuit by moving the hands on a set of dials the same as on a gas meter.

The recording watt hour meter is a very simple device consisting of an electric motor driving several hands on small dials. The speed of the motor depending upon the voltage of the circuit, and the current passing through the field coils and also depending upon what is known as the "Power Factor" of an alternating current circuit, when used with a. c. load.

A rheostat or an incandescent lamp will operate at what is called "unity power factor," that is the voltage and current (the amperes) are in phase with each other. As a general rule, a rheostat is wound in the shape of a coil or spiral which makes it slightly "Inductive" when used on alternating current, but under ordinary conditions

a rheostat or an electric heater and of course, incandescent lamps may be considered to represent "non-inductive" load operating at "unity power factor."

An electric motor, an arc lamp having magnet coils for its regulation, a motion picture arc lamp using an "Economizer," electro magnets and other devices, which contain one or more coils of wire having a number of turns, are put in the class called "inductive" load.

All apparatus in the "non-inductive" load class operate at practically "unity power factor" and if you will refer to formula No. 4, on pages 20 to 22, you will find that in order to obtain the number of watts consumed in any given circuit, the amperes should be multiplied by the volts, and this method of calculating is correct for all "non-inductive" loads.

Apparatus in the "inductive" load class do not operate at "unity power factor," but the current lags behind the voltage or electro motive force, therefore, if you multiply the voltage by the amperes you will obtain a reading which represents what is called the "apparent watts."

In order to measure the "actual watts" a watt meter is necessary because this instrument depends in its operation not only upon the product of the voltage and the amperes, but also upon the phase relation between the voltage and the current. In all circuits carrying "inductive" load the current lags behind the voltage.

Sometimes this lag may be 10 per cent., in which case the system is said to have a "power factor" of 90 per cent. An electric motor may operate on alternating current at an average "power factor" of 60 per cent. A motion picture lamp with an "Economizer" may operate at a power factor of 80 per cent. A fan motor operating on alternating current may operate at a power factor of 50 per cent. The "power factor" becomes lower the more magnetic effect there is in the circuit because the greater the number of ampere turns surrounding iron, the greater will be the magnetic kick as the current reverses, and consequently the current will lag more and more behind the voltage, due to the counter voltage set up by the magnetic kick or reaction in the coil.

If the amperes and the volts multiplied by each other give a certain number of watts, this reading represents the "apparent watts" and in order to give the "actual watts" consumed the "apparent watts" must be multiplied by the "power factor."

The indicating watt meter or the watt hour meter does all this work automatically, whereas, the volt meter, the ampere meter and the old recording ampere hour meter would only indicate the "apparent watts," which would be considerably higher than the "actual watts."

Suppose we have a motion picture arc lamp, with an "economizer" operating on 100 volt a. c. circuit requiring 20 amperes from the line; in that case multiply 100 volts by 20 amperes. This gives 2,000 "apparent" watts.

We will assume that the "power factor" of the lamp and this economizer is 75 per cent. In order to find the actual watts multiply the "apparent" 2,000 watts by the "power factor" .75. This gives you just 1,500 watts or 1.5 k.w., which represents the "actual" watts required per hour for such an arc lamp with the "economizer."

If this same motion picture arc lamp was operated with a choke coil or similar current saving device, on alternating current the amperes "taken from the line would be 50, which multiplied by the 100 volts would equal 5,000 "apparent" watts. The "power factor" of such a choke coil may be about 40 per cent., in which case, we should multiply 5,000 by .40, which would give us just 2,000 "actual" watts or 2 k.w.

Numerous other examples of this sort could be given, but I will go into more detail concerning this matter later in the book.

The watt hour meter as furnished and installed by the electric lighting company is a most accurate and reliable device. It is wrong for any consumer to believe, or even think, that any electric lighting company would willfully make its electric meters run fast or register when no load is on. I have personally had charge of one of the largest electric lighting plants in the United States where thousands of electric meters were in service and, I feel safe in making the statement that 90 per cent. of the errors in meters are in favor of the consumer because the electric meter is a motor and it depends upon its frictionless bearings to keep it operating freely, therefore the least disturbance to which the meter may be subjected, such as the cracking of a jewel, the breaking of the shaft point working on the jewel, the accumulation of dust, the presence of roaches or other insects within the meter, would stop it or make it run too slow. Do you believe that any public service corporation would willfully dare to instruct its meter testers to make a meter run faster than it ought to. Not a bit of it. The risk would be too great, because if one of the employees in the meter department should leave the corporation and could prove that the electric lighting company made a practice of setting its meters too fast, the company would soon be prosecuted. Accidents will happen, but the chances are that if the electric bill is too high and remains high after the electric lighting company has been instructed to that effect and have tested their meter, the large bill is due to your having more load connected to your system or the lamps, and other devices are in use longer than expected. In view of the foregoing, I think you may feel quite safe in depending upon the record of the electric meter.

> The watt hour meter registers only the "actual watts" consumed.
>
> The "apparent watts" required by any load are determined by multiplying the amperes by the voltage.
>
> The "actual watts" are determined by multiplying the "apparent watts" by the "power factor."
>
> The "power factor" is obtained by dividing the "actual" watts by the "apparent" watts.
>
> Direct current devices always operate at "unity power factor."
>
> Alternating current devices, excepting incandescent lamps, certain forms of rheostats, and heaters always operate at less than "unity power factor."

HOW TO READ AN ELECTRIC METER

In order to have a clear understanding of this part of your electric equipment, it is necessary that you should know how to read your electric meter. By understanding how to do this you are not only enabled to check the meter readings at the end of each week, or month, against the readings made by the electric light company's meter reader, but you can also, at your own convenience, read a meter for any given period during the day, or at the beginning and the end of a day, thereby determining for yourself just what it costs you to operate your electric system.

Suppose you want to find out how much it costs you to operate your motion picture lamp on a rheostat. All you have to do is to start the motion picture lamp at the given time, keep it operating for ten minutes with no other lamps or loads on the meter, and, in the meantime, watch your electric meter record the current consumption. If your test is made for a period of ten minutes, multiply the reading by 6, which will give you the current consumption for one hour; and then multiply the product thus obtained by the rate for current per kilowatt hour. This will give you the cost of operating your motion picture lamp with rheostat for one hour.

· If you wish to make a test of your motion picture lamp as controlled by the "economizer," proceed in the same manner and by that method you can, within ten minutes, determine the exact difference in current consumption with rheostat and economizer control. This test could be made in ten or fifteen minutes time, unless you wish to run a half hour or so in order to get the more correct average when no other lamps are burning. You can in that manner get an absolute record of the saving which otherwise could not be had unless you had a separate meter for that part of your installation which you want to test.

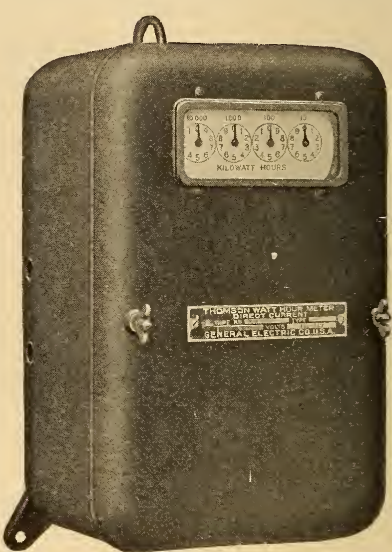


Fig. 36

By the same method you can test any part of your installation as you can read the meter with only that portion of your installation connected to it regarding which you want information.

Through the courtesy of the General Electric Company, I have obtained the latest instructions for reading the electric kilowatt hour or watt hour meter, which I am sure will prove interesting and instructive.

Before proceeding with the directions, I wish to call your attention to Figs. 36 and 37, illustrating the exterior and the interior of the Thomson watt hour meter.

DIRECTIONS

First—Note carefully the unit in which the dials read. On all meters made by the General Electric Company, the figures above or below the dials indicate the value of one complete revolution of the pointer, therefore one division indicates one-tenth of the amount marked above or below.

Second — Note direction of rotation of dial pointers. Counting from the right the pointers of the first, third and fifth dials of the General Electric Company's meters rotate in the direction of the hands of a watch, whereas the pointers of the second and fourth dials move in the opposite direction.

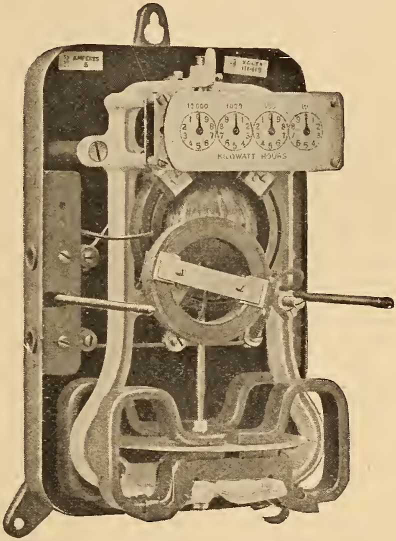


Fig. 37

Third — Read dials from right to left, setting down figures as read.

Fourth—Always read the figure on each dial which has been last passed or is just covered by the pointer.

Note carefully that each dial reading depends on the reading of the one next to it on the right. Unless the one before it has completed a revolution or passed the o, the pointer which is being read has not completed the division upon which it may appear to rest, and still indicates the figure last passed over.

Fifth—See if the register is direct reading, i. e., has no multiplying constant.

Some registers are not direct, but require that the dial reading be multiplied by a constant in order to obtain the true reading. If the register face bears the words, "multiply by ½," "multiply by 2," etc., the actual reading should be divided by two in the first case or doubled in the second, and similarly for other constants.

Sixth—Subtract from the present reading the reading of last month, multiply the difference in kilowatt hours by the rate per kilowatt hour you are paying and you have the amount of your bill in dollars and cents. The ruled section illustrated in Fig. 38 will be found convenient for keeping a permanent record of each month's meter reading.

Month	Present Reading	Previous Reading	Difference
January	....	....	....
February	....	....	....
March	....	....	....
April	....	....	....
May	....	....	....
June	....	....	....
July	....	....	....
August	....	....	....
September ...	....	....	....
October	....	....	....
November ...	....	....	....
December	....	....	....

Fig. 38

Earlier forms of General Electric Company's meters having five pointer dials reading in watt hours. Present types have four pointer dials reading in kilowatt hours.

EXAMPLES OF DIFFICULT METER READINGS

On page 83 will be found examples of difficult meter readings, which may actually occur in practice. For instance, in Fig. 39, the dial on the extreme right reads 900. The second apparently indicates 0; but since the first has not completed its revolution, but indicates only 9, the second cannot have completed its division; hence the second

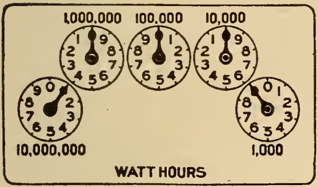


Fig. 39

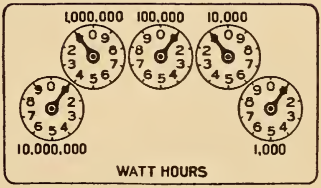


Fig. 40

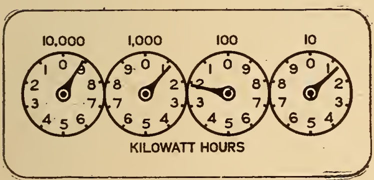


Fig. 41

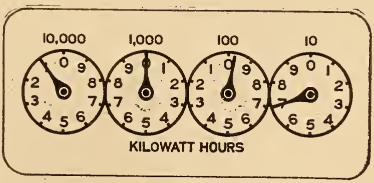


Fig. 42

dial indicates 9 also. The same is true of the hand of the third dial; the second, being 9, has not quite completed its revolution, so the third has not completed its division; therefore we again have 9. The same holds true of the hand of the fourth dial. The last hand (the extreme left) appears to rest on 1; but since the fourth is only 9, the last has not completed its division and therefore indicates 0. Putting the figures down from right to left, the total reading is 999,900, though one might erroneously read 1,999,900, making a mistake of 1,000,000 units.

By similar reckoning the value of other difficult indications may be obtained as illustrated in Figs. 40, 41 and 42.

It is of considerable value and of great satisfaction to any user of electricity to be able to read his own meter; to determine the current consumption for any part of his installation and to calculate the cost, which can be readily done by following the foregoing instructions for reading the electric meter and multiplying the reading in kilowatt hours by the rate per k.w.h.

CHAPTER V

Theater Wiring

ARRANGEMENT OF ELECTRIC CIRCUITS AND LAMPS

A CONSIDERABLE amount of money can be saved not only on the first installation cost, but also in the operation of the electric system for lighting a motion picture theater, by proper placing of the lamps and by selecting the proper style of fixtures. A clear understanding of the subject also permits a proprietor to make the installation attractive to the eye, and another matter of no little importance is the possibility of arranging the circuits so that, in case of accident, certain lamps may be left on while other sections of the electric lighting system are disconnected, as may be necessary on account of fire or other similar accident.

It is the object of this chapter to go into details concerning electric lighting arrangement, and I, therefore, call your attention to Fig. 43, which is a plan view of an ordinary motion picture theater.

The electric company's mains in this instance enter at the front and the main switch box No. 1 is located in the ticket booth, where there may also be located the necessary fuses and switches for the control of all circuits within and outside of the theater.

Switch box No. 1 should contain two main switches; one of which is outside of the meter to shut off the entire electric system. The second main switch shuts off all lamps but the exit and auditorium lamps. In addition to these switches there are of course separate switches which control each set of lamps, for instance:

One switch for the flaming arc lamps.
One switch for the sign.
One switch for lobby lamps.
One switch for exit lamps.
One switch for auditorium ceiling lamps.

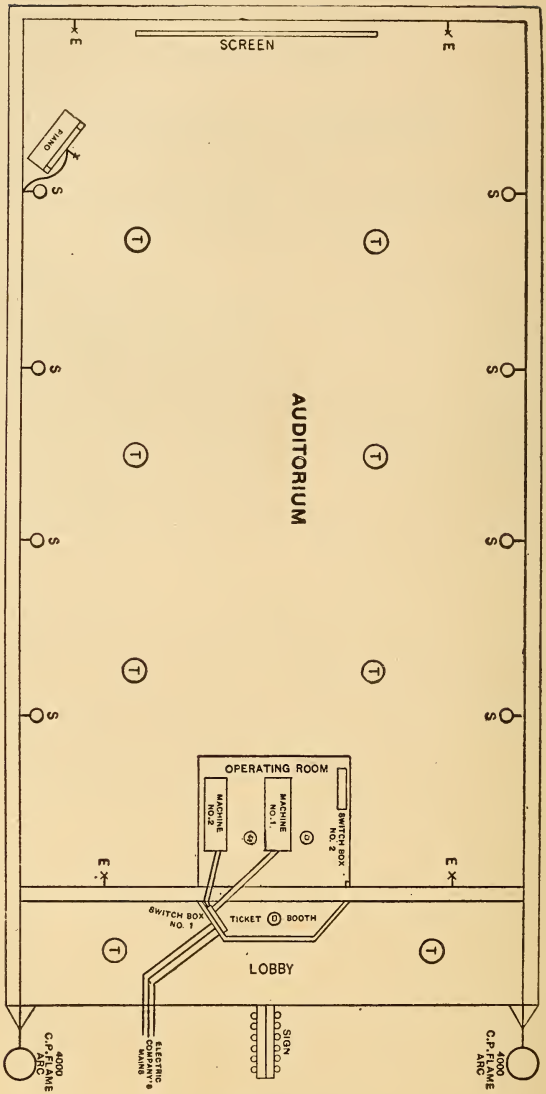

SCREEN
E
E
PIANO
S
T
AUDITORIUM
OPERATING ROOM
MACHINE NO. 2
MACHINE NO. 1
SWITCH BOX NO. 2
SWITCH BOX NO. 1
TICKET BOOTH
LOBBY
4000 C.P. FLAME ARC
ELECTRIC COMPANY'S MAINS
SIGN

Fig. 43

One switch for auditorium side lamps and the piano lamp.

One switch for each motion picture machine, stereopticon or spot-light circuit.

One switch for the lamps in the operating room, ticket booth and any other lamps for special purposes.

There will also be one switch for supplying switch box No. 2 in the operating room, from which the ceiling lamps in the auditorium indicated by letter T can be switched on and off by the operator, but to be connected in shunt with another switch in the switch box No. 1 in the ticket booth. The purpose of this arrangement is to enable the manager or ticket seller to switch on the auditorium lamps, in case the operator should neglect to throw his switch when an accident or fire occurs in the operating room.

This scheme of double control of the ceiling lamps in the auditorium is of great importance and ought to be applied in all new theaters, and would be a good thing to apply in theaters already constructed. In case of fire in the operating room there is nothing which will more assist the proper dismissal of the audience than immediate illumination of the house. If the operator is the only man who can put on the house lights, as is the case in most theaters at this time, the house lights may never be switched on in case of fire in the operating room, because the operator will be too busy trying to put out the fire or to escape from the booth to save his own life, to think of anything else. When a switch is in the ticket booth or at some other convenient point, perhaps outside of the ticket booth, any person can immediately switch on the house lights, notwithstanding the fact that the operator's controlling switch in box No. 2 may be open, as it would be while he is running a picture.

The arrangement, already referred to, provides for the connection of the exit light circuit ahead of the second main switch and fuse, which should be smaller than the first main switch and fuse. The object of this difference in the sizes of the fuses on the main switches is to make it impossible for the exit lights to go out, in case there should be a short circuit on the panel board or in the operating room, which might blow the fuses on main switch No. 2.

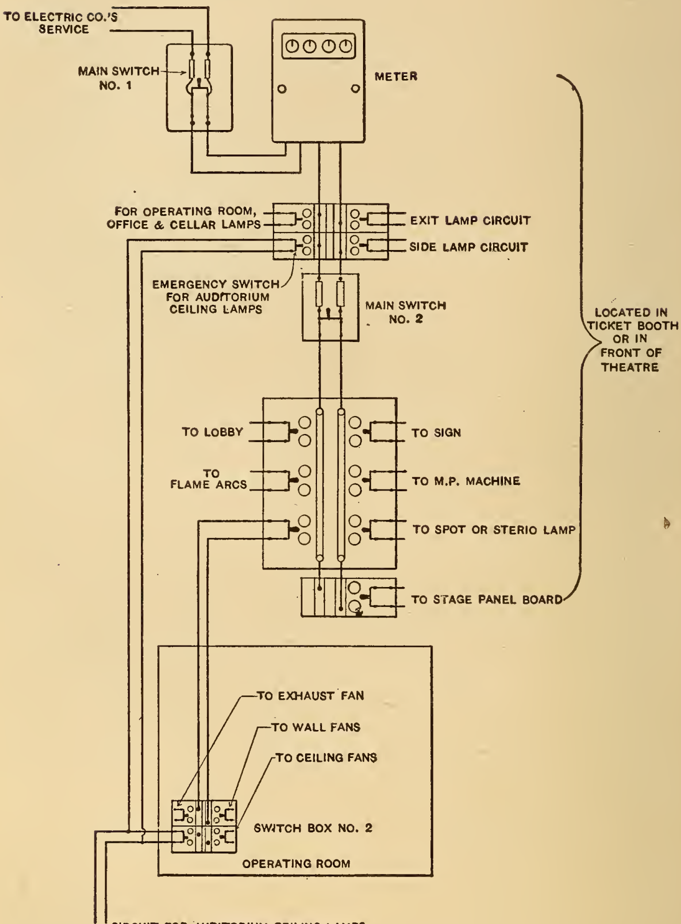

TO ELECTRIC CO.'S SERVICE
MAIN SWITCH NO. 1
METER
FOR OPERATING ROOM, OFFICE & CELLAR LAMPS
EXIT LAMP CIRCUIT
SIDE LAMP CIRCUIT
EMERGENCY SWITCH FOR AUDITORIUM CEILING LAMPS
MAIN SWITCH NO. 2
LOCATED IN TICKET BOOTH OR IN FRONT OF THEATRE
TO LOBBY
TO SIGN
TO FLAME ARCS
TO M.P. MACHINE
TO SPOT OR STERIO LAMP
TO STAGE PANEL BOARD
TO EXHAUST FAN
TO WALL FANS
TO CEILING FANS
SWITCH BOX NO. 2
OPERATING ROOM
CIRCUIT FOR AUDITORIUM CEILING LAMPS

Fig. 44

By selecting proper size fuses, for the different circuits, and by never using a large fuse inside of a smaller one, much trouble from "fuse blowing" can be avoided. There is nothing more annoying and in more instances so likely to cause uneasiness among the audience than to have the house fall into darkness unexpectedly. This should and can be avoided, by simply following the foregoing suggestions, which will be made more clear as we proceed.

> Give most careful consideration to the arrangement of the switches and fuses for the different sets of lamps and circuits in a motion picture theater in order to avoid total darkness of the house in case of accidental blowing of a fuse.
>
> Never put a large fuse inside of a smaller one for any circuit, unless, of course, there is some special reason for so doing; in general there is no such reason.
>
> Consult some competent authority on the electric installation for a theater, as, by so doing, much unnecessary expense can be obviated, and better results obtained.

Emergency and Exit Lighting.—Reference has been made to the necessity, or rather advisability, of providing an emergency switch for the control of the ceiling lamps T in the auditorium, as illustrated in Fig. 43. This emergency switch to be placed in switch box No. 1 in the ticket booth and connected ahead of main switch No. 2 on the panel board in the ticket booth, and then connected on the inside of the house light switch in the operating room, permitting the lighting of the house ceiling lamps, even though the switch for these lamps should be open in the operating room.

Fig. 44 gives a diagrammatic view of the general arrangement of the electrical service, fuses, meter and switches for the various circuits and, when used in conjunction with Fig. 43 in the preceding talk, will be readily understood.

In Fig. 44 the current from the street enters the main switch No. 1, which is equipped with 100 ampere fuses as an illustration. From this point the current passes through the meter. The wires then run from the meter down through the small panel board, or a set of cut-outs, with switches for three or more circuits as follows:

One circuit for exit lamps.

One circuit for auditorium side lamps.

One emergency circuit for auditorium ceiling lamps in shunt with the circuit for these same lamps controlled in the operating room.

There may also be a circuit from this special panel board for office, cellar, operating room ceiling lamps, and other special lamps.

The current then passes through main switch No. 2, which may be provided with 75 ampere fuses, as an illustration.

From this switch the current passes to a panel or distribution board, from which the various groups of incandescent lamps, arc lamps, fan motors, exhaust fans, motion picture machines, spot lights, etc., may be controlled.

This arrangement makes the safest and most convenient means for controlling the electric circuits in a motion picture theater, and should always be applied to new installations, and is also recommended for installation in existing theaters. By the expenditure of a few dollars, the necessary changes in an existing equipment can be made to accomplish these results. Every proprietor and manager will, no doubt, appreciate the advantage of being enabled to instantly light the auditorium ceiling lamps and to maintain the exit and side lamps burning at all times uninterruptedly, although the main fuse on the panel or distribution board may blow—due to an accidental short circuit.

Operating Room Circuits.—It is always well to provide a separate circuit from the main panel board for each motion picture machine, spot light and stereopticon lamp and there should also be a separate circuit from the panel board to the switch box in the operating room, which is referred to as switch box No. 1, and switch box No. 2, in Fig. 43.

Stage Circuits.—Where stage lamps are required, the various stage circuits including footlights, side lights, border lights, bunch lights, dressing-room lamps, flood and spot lights, should be terminated in a suitable panel or distribution board located at a convenient point on the stage from which the stage electrician can control any group of lamps. The stage panel board may then be supplied with current by a circuit between it and the electric service in front of the house, but this circuit should be connected inside of main switch No. 2, so that in case of a short circuit on the stage panel board, the fuses on main switch No. 2 will blow, leaving the exit side and auditorium lamps still burning.

Expert Advice.—It takes years of experience and intimate knowledge of the peculiar lighting requirements of a theater to lay out the electrical equipment. It is surprising how few architects and electrical contractors understand these requirements, and this accounts for the fact that, in many instances, installations are almost completed when changes have to be made often at considerable expense to the owners.

Much expense and trouble can be saved by employing, or consulting experienced, competent authority on these matters, and the saving not only means reduced cost of the first equipment, but also considerable saving on cost of operating.

There are so many inferior electrical devices on the market, and new and improved devices are offered for sale almost every day, that the average man, even though in the electrical business, is not always up to date, and this is anothe reason why the best authority is none too good.

Have specifications and plans prepared, no matter how small the job may be, and have specified therein the quality and specific style of fixtures and goods wanted and let every bidder furnish a proposal on the same style and class of equipment, thereby putting each bidder on an equal basis, which will enable the owner to then choose with justice to himself and the bidder. The lowest bid is not always the cheapest, because workmanship and honesty in carrying out the work contracted for are worth more than the difference in some bids.

The front of a motion picture theater is generally the safest and best place to locate the electric service switches and panel or distribution board.

The service switches and distribution board if placed in the ticket booth should be accessible from the outside, by means of a door or window enabling the manipulation of the switches from the outside in case of fire.

All switches should be properly labeled.

There should be two main switches; the first one having a 25 per cent. to 50 per cent. heavier fuse than the second switch, and between these should be placed the cut-outs and switches which control the circuits for exit and auditorium lights.

LIGHTING FIXTURES AND LAMPS

In making selection of electric lamps and fixtures for the illumination of a motion picture theater, one is confronted with a dozen or more types of electric lamps, and hundreds of different designs and styles of fixtures, so that the selection of these is rather difficult, unless some general rule is followed.

You must approach this subject with your mind made up to secure an efficient, practical and artistic equipment. All of these good qualities cannot always be had at the lowest price, but suitable equipment can be had at a sufficiently low price to warrant anyone, when building a motion picture theater, to consider only a proper equipment, and it is the object of this section division to give you a few pointers on what may be considered good methods.

OUTSIDE ILLUMINATION

The Flaming Arc.—For the outside of a motion picture theater I do not believe there is any illuminating medium which is as economical and, at the same time, as effective in drawing patrons to the front of the theater, as the flaming arc lamp. The flaming arc lamp is a comparatively recent invention, and two lamps are usually operated in series on either direct or alternating current. A good lamp of this type will produce over 3,000 candlepower and carbons, for it can be had giving either golden yellow, or a brilliant white light. The flaming arc lamp is comparatively simple and, if properly taken care of and trimmed, will last a long time. Two flaming arc lamps cost anywhere from $100 to $125 installed, and two lamps together consume approximately one kilowatt of current per hour, which, at the ten-cent rate, makes the operation of the two lamps about ten cents per hour, with an additional expense of about one and one-quarter cents per hour for each lamp for carbons.

The Electric Sign is another attractive illuminating medium for the front. It can be made as plain or as elaborate as desired, costing anywhere from $50 to $1,000 or more. A cheap inartistic sign is, in my opinion, not a paying investment. An attractive electric sign costs a great deal of money to put in and also costs a considerable amount to operate. The average price for a good sign for a motion picture theater is about $200 complete, installed, and the cost of operating such sign is about 20 to 40 cents per hour at the ten-cent rate, depending, of course, upon the number of lamps required.

Decorative Front Lighting.—Another attractive form of exterior illumination for a theater, is the outlining of the front with a number of 2 or 4 candle-power incandescent lamps. These lamps can be arranged in many attractive ways and, by selecting different and harmonizing colors, beautiful effects can be obtained. But this form of lighting is expensive to install and quite expensive to operate. As a guide, I may state that at the ten-cent rate for current, it costs about two-tenths of a cent per hour for each 4 candle-power lamp and twelve one-hundredths of a cent for each 2 candle-power regular carbon filament lamp.

Advertising Value.—The value of an electric sign, or decorative lighting, in front of a theater, can be increased considerably by the use of electric flashers to switch groups of lamps on and off, making an animated and brilliant display. In the larger cities, these more or less fancy illuminations pay because of the transient trade, which in that way can be attracted, but I do not believe that any great expense for outside lighting display is warranted in a smaller town or in settled districts where there is no competition.

Remember, that the exterior illumination of a theater takes the place of the newspaper advertisements of a regular business house and is intended to attract the attention of the public. A theatrical manager can make no worse mistake than to spend a lot of money on the outside of his theater at a sacrifice of his program. If he does, he is in the same position as the merchant who advertises extensively and then does not have the facilities for selling or delivering the goods properly and promptly. The answer is the same in both cases, the public may bite once, but not the second time. It is far better to use a moderate amount of display lighting outside and making the exhibition on the screen the best that can be produced, because that is what counts.

Lobby Illumination.—The lobby of the ordinary motion picture theater is, as a general rule, a comparatively small space to illuminate, especially in the larger cities where ground is valuable. It is not necessary to make a very extensive display of electric lamps in a lobby, because it can be seen only from across the street, and therefore, sufficient illumination of entrances and exits, and to enable the public to read your signs, is all that is necessary. It is, of course, a matter of taste with each individual owner as to how far he should go in the decorative illumination of the lobby of his theater. I feel, however, safe in recommending two or more simple, but artistic and efficient fixtures; each one equipped with a large Tungsten lamp for emergency use when the flaming arcs are out for any reason. These may be of any desired size from 60 to 250 watts.

Figs. 45 and 46 give a good idea of fixtures for lobby illumination. Fig. 45 is a simple, one-light ceiling pendant fixture, equipped with a keyless socket, glass shade and Tungsten lamp of proper size. This fixture is plain, durable, inexpensive and efficient.

Where a more ornamental fixture is desired, something along the style of Fig. 46 may be used or any other fixture possibly in the way of a lantern or something similar. The fixture in Fig. 46 is practically the same as that shown in Fig. 45, but to it, is added a shade which may be on the Japanese style made of bamboo frame with colored paper or silk body having a glass bead fringe at the bottom, or where a more permanent and expensive fixture is desired, this general design can be had with the dome made of leaded glass. When the ceiling of a lobby is low, the lamps may be put in a receptacle close to the ceiling, doing away with the stem of the fixture. A very pretty effect can also be had by a regular ceiling fixture having an 8 to 12-inch frosted, colored, or cut glass bowl under the lamp fitting in a ring screwed against the ceiling. Rich effect can also be had by installing a handsome three-armed bracket on each side wall of the lobby and possibly one on each side of the ticket booth window.

I have noticed many installations where incandescent lamps have been applied for decorative illumination of

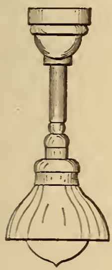


Fig. 45

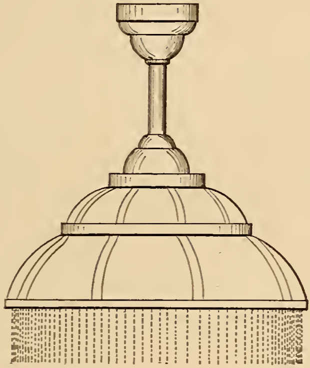


Fig. 46

the lobby and where this form of lighting has been a complete failure, and only in special instances do I recommend the placing of incandescent lamps in rows and circles, for the decorative illumination of a lobby, but only when you have decorations worth while showing.

Flaming arc lamps are, as a general rule, the cheapest and most efficient illuminating medium for the exterior of motion picture theaters.

Electric signs can be used to advantage in some cases, but are generally too expensive and are, in most instances, unnecessary.

Incandescent decorative lamps in front of a theater are attractive, but too expensive to install and operate and are not generally necessary.

Simple and artistic electric fixtures, preferably few in number, make good form of illumination for the lobby of a motion picture theater.

INTERIOR FIXTURES

The motion picture theater is essentially a dark place, which outside of a limited amount of illumination requires very seldom any great amount of light. It is, of course, understood that where vaudeville (which should have no place in a first-class motion picture theater) is used, it may be necessary to provide a considerable amount of general illumination, but under normal conditions a motion picture theater confined to the exhibition of pictures, and illustrated songs, needs only a fair amount of general illumination in order to enable the proper discharge of the audience at the end of the performance.

It is well to provide sufficient subdued illumination during the entire time the theater is open to enable anyone to find a seat while the picture is on the screen. When pictures were first put in theaters, it was thought necessary to have the house absolutely dark, excepting for a few exit lights, but the tendency of to-day is to have the house partly lighted all the time. This necessity for illumination during the time the picture is shown, calls for proper, and in some instances skillful application of lamps, in order not to interfere with the picture, and at the same time give a fair amount of general illumination.

Many proprietors have made the mistake of equipping their theaters with rows of incandescent lamps in the ceiling of the auditorium, and in some instances, I have observed the entire frame for the screen outlined with incandescent lamps. These installations are not only expensive to install and to operate, but they are in most instances unsightly, unless very carefully arranged on specially constructed and ornamental ceilings. There can be nothing more offensive to the eye than to have the picture disappear from the screen and then have the screen illuminated by incandescent lamps placed on the frame. This arrangement gives a brilliant display of light which is disagreeable and besides it causes the pupil of the eye to contract, so that when the picture is put on again, it takes the eye quite some time to adjust itself to the sudden darkness and to the much milder light on the screen when the picture is put on. It is only natural that this method takes away from the effect of the picture at least for some time, after it is put on and should, therefore, be avoided as much as possible.

The general illumination of the auditorium can, of course, be had in many different ways. Fixtures and lamps costing from a few dollars each to $100 each, may be put in at the option of the owner. But why should a great amount of money be expended for the purpose of ceiling lighting when it is not required in a first-class motion picture theater at any time excepting during the short space of time the theater is being filled or at the end of the performance in the evening when the audience passes out? Great expense for the general illumination of a motion picture theater is in most cases not warranted. Let us look back to Fig. 43 on page 86, where you will find a number of electric outlets designated as follows:

E are exit lamps, which in the cheaper theater may be ordinary incandescent lamps of 2 or 4 candle-power, colored red. In the more expensive theaters special signs may be provided over each exit, consisting of a metal box having the words "Exit" in letters four to eight inches high, with the outline of a hand pointing to the location of the exit, if necessary, as illustrated in Figs. 49 and 50.

S are brackets which may be of any suitable design, for instance, like Fig. 47, which is about the simplest and cheapest type available for the purpose. More elaborate fixtures can be put in if necessary. Fig. 47 with a 25-watt Tungsten lamp will answer for all general purposes, and it is well to have the side lights of the combination gas and electric type so that in case of failure of the electric current, the gas burners can be lighted in a few moments.

T are the ceiling outlets. Fixtures for these can be of a design similar to Figs. 45 and 46, consisting of an ordinary pendant or ceiling fixture in the socket of which may be supported a large Tungsten lamp varying in size from 60 to 250 watts, as may be required. These fixtures can be equipped with the ordinary glass shade or a more

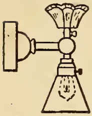


Fig. 47

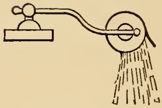


Fig. 48

RIGHT

Fig. 49

LEFT

Fig. 50

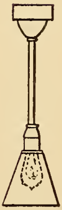


Fig. 51

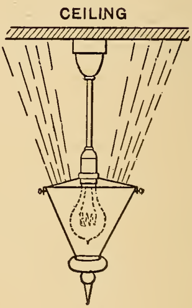


Fig. 52

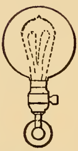


Fig. 53

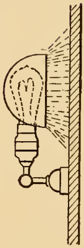


Fig. 54

ornamental dome shade can be put on, making the installation simple, but at the same time substantial, efficient and attractive.

For the piano a suitable fixture with 4 candle-power lamp is sufficient and a design something similar to Fig. 48 standing on top of the upright piano, having its shade adjusted to throw the light on the sheet music, is very desirable. No make-shift should be allowed for a piano lamp, because it is important that as little light as possible be reflected or directly visible to the audience.

The subdued illumination during the time the picture is on the screen can be secured from special brackets or fixtures provided with very deep cone shades or other suitable reflectors, which will allow the light to be thrown in any direction desired, but under no circumstances must this light be directed against the screen, nor against the audience.

Fig. 51 may be a simple pendant fixture with a socket having a 25-watt Tungsten lamp provided with a very deep cone shade. This fixture will throw the light downward and the depth of the cone shade as well as its narrow angle will practically conceal the lamp.

Fig. 52 is similar to Fig. 51, but in this case the cone shade is reversed, and of wider angle, allowing the light to be reflected against the ceiling, which gives a very desirable general illumination while the picture is being exhibited.

Fig. 53 is a side bracket, which may be installed in place of bracket S on Fig. 43, or these brackets may be installed in addition to the regular side bracket fixtures used for general illumination.

Fig. 54 gives a side view of bracket Fig. 53 and illustrates how the light may be reflected against the wall, giving a soft and diffused illumination.

The 25-watt Tungsten lamps used in Figs. 51, 52, 53 and 54 may be colored to suit the ideas of the manager. I have found that lamps colored amber give the best results.

Indirect Lighting.—Where the design of the ceiling permits, and the decoration warrants the illumination of the ceiling, the auditorium as well as the lobby may be

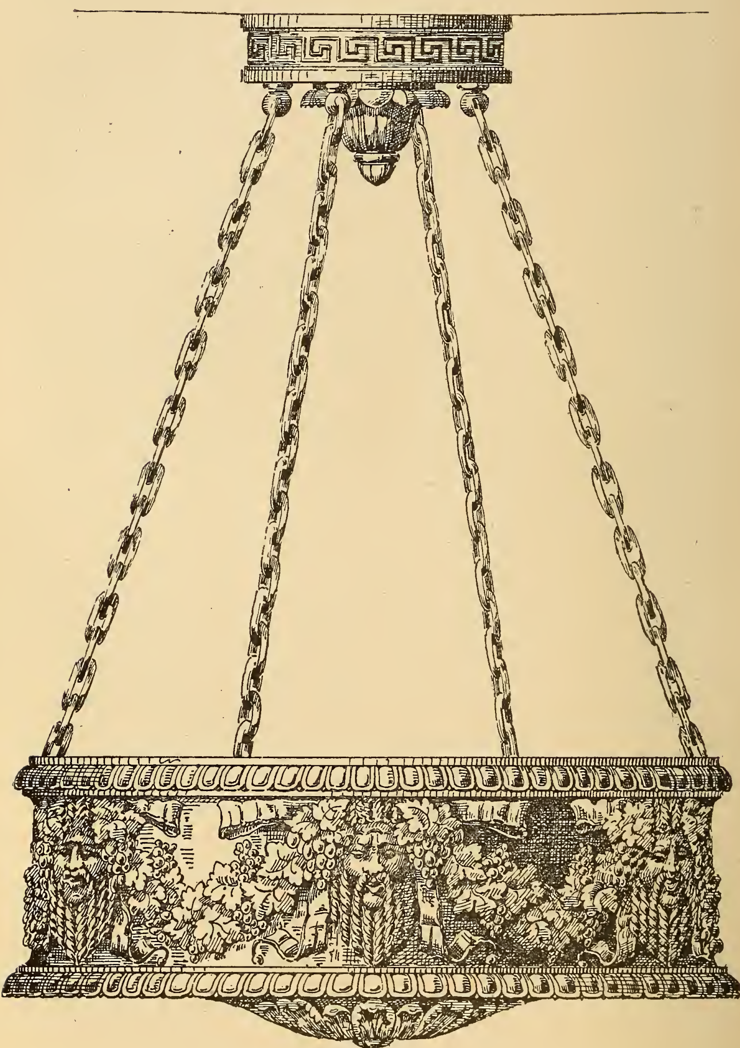


Fig 54-A

illuminated by indirect lighting fixtures. These fixtures can be had in many varied designs. The plain ones, consisting of a reflecting bowl fastened to a stem with canopy from the ceiling or hanging on three chains or hooks, selling at anywhere from $7 to $10 each. The more ornamental indirect lighting fixtures, as illustrated in Fig. 54A, sell at anywhere from $15 to $100 each, depending upon the size and the design. The use of these fixtures eliminates entirely the downward rays of light. The light is reflected from the inside of the bowl against the ceiling, by which means it is evenly diffused throughout the auditorium. It is evident that this form of fixture shows to best advantage where the ceiling is well decorated and finished to make an ornamental appearance.

The same form of fixture may be equipped with a semi-transparent or opal bowl, in which case the illumination becomes semi-indirect. This means that part of the light will be reflected from the inside of the opal bowl against the ceiling, and part of the light will be diffused through the opal bowl, which will radiate a soft light, the intensity of which will depend upon the thickness and density of the glass and the size of the lamp used. The semi-indirect fixture is illustrated in Fig. 54 B, and beautiful results can be obtained with these fixtures by using tinted or colored lamps. The lamp within the bowl may be dipped or otherwise colored, an amber color, for instance. This will soften the light and give a very pleas-

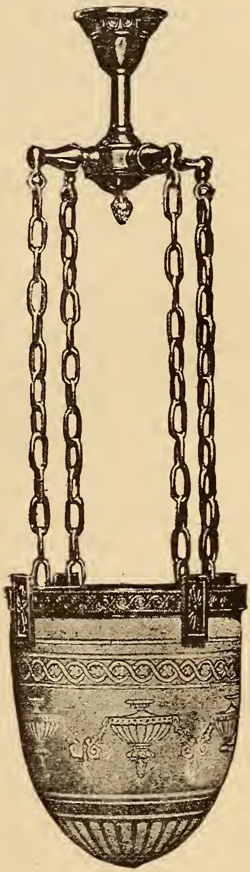


Fig. 54-B

ing effect in the auditorium, or in the lobby, for which this style of fixture is equally well suited. The decoration of the ceiling is not so important with the semi-indirect fixtures, because any apparent lack of, or defect in, the decoration will not be so noticeable as when the straight indirect lighting fixture is used. In the more modern theaters the indirect as well as the semi-indirect style of lighting for the auditorium has been generally adopted. The principal advantage of this system lies in the fact that the auditorium may be kept well illuminated without detracting from the clearness and brilliancy of the motion picture. There is also the advantage that seats may be readily found by incoming patrons without the help of an usher.

Unless the ceiling of a theater is of ornamental and artistic design, it is not good practice to install groups or rows of incandescant lamps for general illumination of a theater. Simple pendant fixtures with large Tungsten lamps with a suitable reflector or shade are preferable and proper.

Do not put incandescent lamps on the frame of the motion picture screen.

Use a piano lamp of proper design to confine the rays of the light to the sheet music.

If possible, use combination gas and electric fixtures for the side lights.

Install a limited number of lamps for general illumination while the picture is being exhibited but take care that the light rays from the lamps are confined to given directions, and the illumination from these must never strike the screen nor be within direct vision of the audience.

CHAPTER VI

Direct Current Projection

ELECTRICITY is a force of power usually transmitted over a circuit of copper wire, and as long as the two wires are insulated from each other this force or power is confined to the wires and is available for the production of heat, light or power at any point of the circuit.

It has been stated previously that electricity may be produced by chemical action, as in the galvanic battery, and also by mechanical force exerted upon the rotating element or part of an electric generator also, called a "Dynamo."

In order that you may understand in the most elementary way what takes place in an electric circuit, incandescent lamp or arc lamp, when the electric current passes through it, I have thought of, and herewith present, a few simple comparisons, which I hope will enable you, in your own way, to grasp and understand the reason why a wire gets hot; why the incandescent lamp glows and the arc gives a brilliant display of light rays.

The first example, or comparison, will be a cannon ball moving at high velocity through still open air, under which condition its movement would be retarded to the lowest extent (unless, of course, we could imagine the ball flying through a vacuum without the effect of the influence of gravity or other similar force), the same as the electric current is retarded to the least extent when moving through a conductor in which the resistance to the current is very small.

Now let us force the cannon ball through an opening like a tube for instance. Under this condition the ball will be retarded to an extent depending upon the diameter and the length of the tube. If the tube is very long the resistance will be greater. If the tube is small in

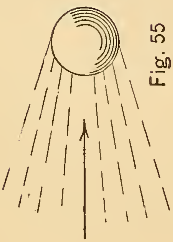


Fig. 55

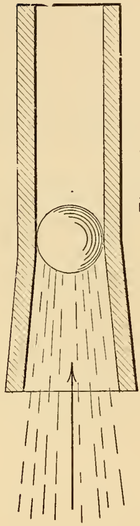


Fig. 56

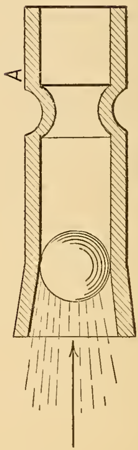


Fig. 57

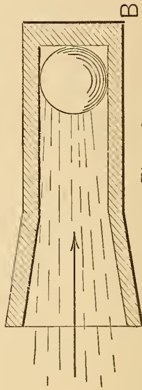


Fig. 58

diameter relative to the ball, the retarding effect will be still greater, due to the friction between the inside surface of the tube and the ball. If the tube which retards the movement of the ball is massive, the friction will simply stop the ball, or at least diminish its speed greatly, and there will be no other noticeable effect, because the mass of which the tube is composed will have absorbed and dissipated the heat generated by the friction.

If, however, the tube is made of comparatively thin material, then the friction created might be great enough to make the tube heat to such an extent that it will glow and give out rays of light. If the tube were made still smaller in diameter the friction might be great enough to melt or ignite the material of which the tube is made. If the end of the tube is sealed up, the tube may glow, due to the friction throughout its length, but at the end of the tube where the ball strikes the stop, there will be an explosion, which manifests itself in stopping the ball or destroying the end of the tube—tearing or melting it away, as the case may be. The greater the speed of the ball, and the larger and heavier it may be, the greater will be the effect it can produce, and, as above stated, this effect may show itself in the shape of heat, light or concussion with consequent destruction, until the ball finally stops.

Let us imagine a rapid-firing gun forcing one ball after another through a tube some distance away from the gun; in this case we could make the tube heat to such an extent, due to the friction, that it would glow and be a source of heat and light, proving to you that almost any moving body or force creates heat if its movement is retarded or minimized.

For a clearer explanation I submit Figs. 55, 56, 57 and 58.

Fig. 55 illustrates a cannon ball in motion in a given direction through space, just the same as an electric current would travel over a circuit of low resistance.

Fig. 56 illustrates the cannon ball entering a tube where its motion is retarded, which creates friction, and the result is heat and possibly a glow and consequent generation of light in the tube. This is the same as when an electric current is forced through a circuit which is too small for the quantity of amperes, making the wire heat and, under some conditions, causing the conductor to glow, giving off heat as in electric heater, or rays of light as in the incandescent lamp, also called the "glow lamp."

Fig. 57 illustrates the cannon ball entering a tube which is contracted at the point A, causing a part of the energy stored in the moving ball to be dissipated at the point A, due to friction giving off heat and possible melting or destroying the tube at the point A.

At this moment I want you to imagine that we could replace the destroyed material at A as rapidly as the successive cannon balls passing through the tube expend their force at this point through friction, giving off heat and possibly light. The effect of this arrangement, if it were practical, would be to produce a constant source of heat, and possibly light, at point A, giving us a comparison with the electric arc as follows: The tube in Fig. 57 joined together by the obstruction A takes the place of the two carbons in an arc lamp. The obstruction A represents the electric arc, and the successive cannon balls represent the electric current passing from one carbon over the air gap, producing the arc, then over the second carbon back to the line, thus completing the continuous circuit and performance.

Fig. 58 illustrates the moving cannon ball encountering a dead stop at B, at which point the ball will either stop or expend the power within it with great force destroying the end of the tube, and this illustration gives an excellent comparison of the effect of an electric current when the carbon separation is so great that the arc cannot be maintained, causing the current to stop flowing, or, in representing a short circuit when the two carbon points are put together without sufficient resistance or other protecting element in the circuit, in which case there would be a great deal of power expended at the carbon points, resulting in an explosion and consequent destruction of the apparatus.

It is extremely difficult to make this matter much clearer to you because the electric current is a continuous force, whereas in the instance of the cannon ball the force is necessarily intermittent, and besides, it is possible to stop the flow of current by simply separating the two wires, whereas with any other forces or power the stopping of the movement cannot be effected without trouble and great loss due to the momentum or inertia of the moving body which has to be brought to a standstill. Electricity has no momentum or inertia: it stops the instant the contact is broken and starts instantly, exerting full power the moment the contact is made.

The Voltaic Arc.—When an electric current passes through a conductor, there is a loss caused by the resistance of the conductor to the passage of the electric current, which manifests itself in heat.

If at a given point the conductor be made small in cross-section, or be made from a material of relatively high resistance, a considerable amount of heat will be generated at such point; in fact, the wire can be made to glow and give light.

When the terminals of an electric circuit are separated, there will be a gradual increase of resistance to the passage of current at the point of separation, and with small currents of comparatively low voltage, when the terminals are separated further, there will appear a small spark. This spark, which was in the early days produced by the current from galvanic batteries, was called by some of the early experimenters the "Galvanic Spark."

The voltaic arc was probably first observed, and experimented with to a considerable extent, by Davy, in 1802. Davy attached to the poles of a large battery, composed of a great many cells, wires connected with carbon rods, which he first allowed to touch each other and then, when slowly separating the carbon points, he obtained a brilliant light or flame, nowadays referred to as the "Electric Arc."

For a general explanation of the voltaic arc, I quote T. O'Conor Sloane, A. M., E. M., Ph. D., as follows:

The voltaic arc is the arc between two carbon electrodes slightly separated, which is produced by a current of sufficient strength and involving sufficient potential difference. The pencils of carbon are made terminals in a circuit. They are first placed in contact, and after the current is established they are separated a little. The current now seems to jump across the interval in what sometimes appears an arc of light. At the same time the carbon ends become incandescent. As regards the distance of separation with a strong current and high electro motive force, the arc may be several inches long.

The voltaic arc is the source of the most intense heat and brightest light producible by man. The light is due principally to the incandescence of the ends of the carbon pencils. These are differently affected. The positive carbon wears away and becomes roughly cupped or hollowed; the negative also wears away, but in some cases seems to have additions made to it by carbon from the "positive" pole. All this is best seen when the rods are slender, compared to the length of the arc.

It is undoubtedly the transferred carbon dust which has much to do with this formation. The conductivity of the intervening air is due partly, perhaps, to this, but undoubtedly in great measure to the intense heating to which it is subject. But the coefficient of resistance of the intervening air is so much higher than that of any other part of the circuit that an intense localization of resistance occurs with corresponding localization of heating effect. This is the cause of the intense light. Thus, if the carbons are but 1-32 of an inch apart, as in a commercial lamp, the resistance may be 1½ ohms. The poor thermal conductivity of the carbon favors the concentration of heat also. The apparent resistance is too great to be accounted for by the ohmic resistance of the interposed air. A kind of thermo-electric effect is produced. The positive carbon has a temperature of about 4,000° C.

(7,232° F.), the negative from 3,000° C. (5,432° F.) to 3,500° C. (6,322° F.) This difference of temperature produces a counter-electro-motive force, which acts to virtually increase the resistance of the arc. The carbon ends of an arc can be projected with the lantern. Globules are seen upon them, due to melted silica from the arc of the carbon.

From the foregoing we learn that the electric arc is simply an effect produced by electric current passing from one conductor to another over a gap of comparatively high resistance.

The electric arc may be produced between terminals or electrodes of metal, in which case it is called a "metallic" arc. The metallic arc, as compared with the ordinary carbon arc, is greater in length for the same amount of power applied, is more likely to flame, due to the more rapid volatilization; and the color of the flame varies, also depending upon the material used for the metal terminals between which the arc is struck.

The motion picture operator is, for the present at least, most interested in the electric arc as produced between two carbon points by either direct or alternating current as required for the usual form of stereopticon, spotlight and picture projector.

For convenience I will divide the subject into two main sections, as follows:

(1) Direct current projector arc. (2) Alternating projector arc.

THE DIRECT CURRENT ARC

I will try now to give you a correct representation of what takes place under different conditions when an arc is struck and maintained between two carbon electrodes with the direct current.

Experimenters with the electric arc many years ago determined that carbon, as it is generally known, is the best material for electrodes between which an arc may be maintained. It was further determined that for open arc, carbon arc lamps having an automatic feed on constant potential direct current circuits, the arc should not be longer than required to give a potential drop of 40 to 45 volts. It was further determined that for best results the positive carbon or electrode should be of the cored type (which means that the carbon has a hole through its center, into which is tightly packed powdered carbon, sometimes mixed with chemicals or metallic salts), and

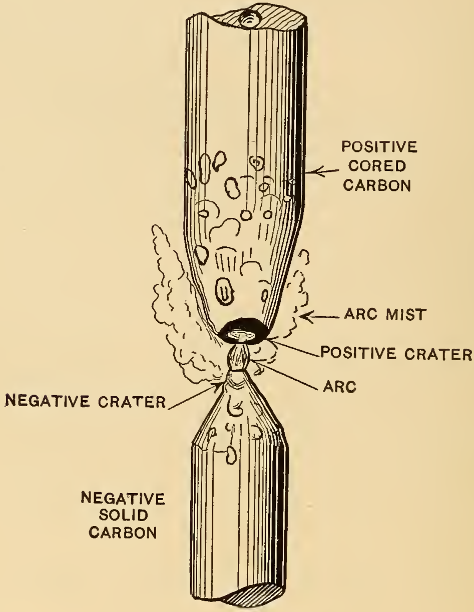


Fig. 59

for the negative electrode it was found that a pencil of solid carbon, smaller in diameter than the upper carbon, on account of the unequal consumption of the two electrodes, would best serve the purpose.

We will take for granted that the rules established by experimenters during the past twenty-five years, as previously referred to, still hold good.

Fig. 59 illustrates two carbon electrodes between which a direct current arc is maintained. The upper electrode is a ⅝-inch soft-cored carbon; the lower is a ½-inch solid carbon.

I have purposely separated the carbon points more than would be the case in actual practice with a 40 to 45-volt arc; in fact, the distance illustrated is about a third greater. I have done this in order to get better opportunity to separate the various elements to make the illustration plainer to you.

You will note a flame represented by dotted lines extending from the lower carbon point around the upper carbon. This flame is composed of highly heated gases with which are mixed light incandescent particles of carbon, silica, etc., which are constantly carried upwards by the induced draft.

Before going further I want to speak about the "arc mist," because it is a detriment to the arc, in a measure acting as a cloud between it and the observer. Experience proves that the "arc mist" is greater with impure and heavily cored and copper coated carbons. The "arc mist" is considerably less between two solid carbons or between chemically pure carbons, but unfortunately chemically pure carbons are not readily obtained and the resistance of the arc with solid carbons would be considerably higher, making it necessary to keep the carbon points so close together that the negative crater would almost hide the positive. This would make the arc inefficient for general purposes, although it might possess a higher individual or intrinsic crater efficiency.

Referring again to Fig. 59, we see there an illustration of a normal direct current arc maintained between proper carbons, the positive carbon is cored, and the negative is solid. The positive crater, it is conceded, furnishes more than 75% of the total illumination, and this is very important for many purposes, because it centralizes the illuminating point in the crater of the positive carbon, permitting the crater to be used for projection. The illumination from the negative crater need not be considered at all, and the illumination from the arc proper to a very small value. As a matter of fact, the arc in a direct current projector lamp is really only necessary to maintain the high temperature in the positive crater. In view of this fact, it becomes necessary to centralize all possible energy at the positive crater and everything possible should be done to maintain the carbon separation only great enough so that the negative carbon point will not interfere with the emission of light from the positive crater, and we should also reduce the arc mist to a minimum by using a solid negative carbon.

In Fig. 59 the small bubbles or globules, above the

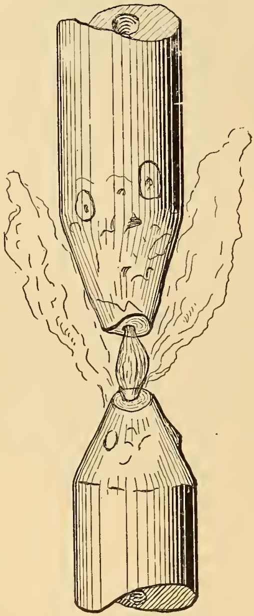


Fig. 60

Fig. 61

positive crater and below the negative crater, are intended to show the accumulation of impurities in the carbon. These generally drop off without being consumed, and fall in the bottom of the globe or lamp house, if in a projection lamp.

Fig. 60 illustrates what takes place when two cored carbons are used. The arc separation becomes longer for the same voltage drop, and the arc mist is almost 50% greater, thereby making this form of arc less efficient, and more likely to be unsteady on account of draft interference.

Fig. 61 illustrates how a 45-volt open arc looks, maintained between two solid commercial or ordinary carbon points. You will note that the points burn flatter, and a cap formation is present, on the lower carbon point in particular, and the lower carbon point covers almost entirely the positive crater, which makes this form of arc useless for projection purposes. Of course, if a higher arc voltage is applied, greater carbon separation is possible, but this would make the arc unstable, unless enclosed in a small glass globe, which would make it still more undesirable as a projector arc.

> From the foregoing you can make up your mind that the best direct current arc for projecting purposes is formed and maintained between cored positive and solid negative carbons, and it is essential that these carbons should be as pure and of as high grade and as much uniformity of manufacture as possible. For direct current it is wrong to use two cored carbons, although it is permissible, and it is also wrong to use two solid carbons.

We have found that the direct current open arc is for practical purposes easiest maintained between one cored positive and one solid negative carbon, and that for automatically feeding lamps, such as were used some years ago and are to-day used for special purposes, including automatic stereopticons and certain forms of stage lighting apparatus, automatic searchlights, etc., the arc voltage or potential drop across the two carbon points should not exceed 45 volts. As a matter of fact, it may vary between 40 and 45 volts.

For direct current motion picture projector arc lamps, which are, as a general rule, of the hand-feed type, this arc voltage is too low. It is more desirable and convenient to use a higher arc voltage, varying between 50 and 60 volts, but for best results the arc voltage should not exceed 55 volts.

There are two reasons for the desirability of maintaining a somewhat higher arc voltage for motion picture arc lamps. The first reason may be briefly stated, greater flexibility is obtained, making it possible to feed sufficiently often by hand without losing the arc. In this connection you may be interested in knowing that:

> It is for general purposes impractical to operate an open direct current arc below 38 volts, and it is equally impractical to operate such arc at a voltage greater than 58, because the hissing point begins at about 38 volts and the flaming point of the arc at 58 volts.

It is therefore evident that it is not safe to maintain the arc voltage with direct current below 40 nor above 58, somewhere between these two points can be found the most efficient arc voltage for any desired purpose. You cannot judge the arc voltage by the distance between the carbon points, because the resistance of the arc depends upon several factors, including:

1. The make of carbon used.
2. The style of carbon (cored or solid).
3. The number of amperes passing through the arc.
4. The composition of the core filling of the carbon.
5. The admittance of oxygen (air) to the arc.

The only correct way to determine the voltage drop across the arc is by a volt meter.

The second reason for the desirability of a slightly longer arc with direct current motion picture projector lamps, is that it enables one to separate the two carbon points sufficiently, so that the negative carbon will not interfere with the light rays from the positive crater. You should understand that with a low arc voltage and consequent short arc the negative carbon point would cast a shadow, as it were, or be in the direct path of light from the positive crater, materially reducing the amount of light available.

The question of setting the carbons relative to each other as well as to the condensing lenses is a matter of utmost importance, and here again there are fundamental rules which will serve as a guide in securing the most practical and efficient carbon setting for any given purpose.

It is conceded and understood that the positive crater is the only element to be considered in connection with direct current arc projection.

CARBON SETTING

The Right Angle Arc.—It would seem, on this account, that a lamp having the crater of the positive carbon facing the condensing lens would be the most efficient, and this is true, provided it is possible to sufficiently localize the positive crater and maintain it in a given position and of uniform intensity. Some of the manufacturers of high-class stereopticons, appreciating the value

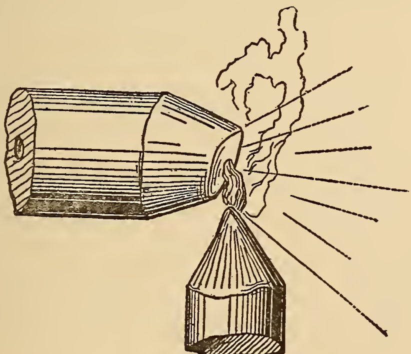


Fig. 62

of what is called the "right angle" arc lamp, equip their lanterns with "right angle" lamps with splendid results.

Fig. 62 illustrates the relation of the carbons to each other in the "right angle" arc lamp. You will note the positive crater facing the condenser allows almost all available light to become concentrated by the condenser. This condition of ideal crater formation could be maintained if no outside interference were present. But there are interferences sufficiently great to distort the arc so as to make it unstable unless a comparatively small amount of current is used and unless the carbons are set and fed exactly as they ought to be.

The setting as in Fig. 62 may be acceptable for stereopticon work where 10 to 15 amperes will produce the required results.

For motion picture work, however, the requirements call for anywhere from 25 to 60 amperes with direct current at the arc, and under these conditions the effect of the interferences (which may include magnetic effect and drafts) becomes so great that the arc will "stretch," as you might term it, burning sometimes on the upper edge of the crater and at other times on the lower edge; in other words, the arc becomes very unsteady, and as a result the temperature of the crater is also subject to sudden variations, which, of course, make the illumination on the screen unsatisfactory. I don't mean to say that it is impossible to operate a motion picture arc as shown in Fig. 62, but it is impractical, and besides the arc lamp required is much more complicated and more difficult to handle. In view of the foregoing it may be said that, while the "right angle" carbon setting for a direct current projector lamp as illustrated in Fig. 62 may be the most efficient from a theoretical point of view, it is not practical for motion picture work. Manufacturers of stereopticons who are using the "right angle" lamp for stereopticon work, appreciating this fact, are not using the "right angle" lamp for the lower lamp house where the lower lamp of a dissolving outfit is to be used in connection with a motion picture machine.

Variable Angle Setting.—While theoretically the right angle carbon setting for direct current should give the best results possible, in practice, however, it does not give good results where more than 20 amperes are used at the arc—for motion picture projection.

This fact, as demonstrated in actual practice, has made it necessary to build hand-feed arc lamps for motion picture projection, which will permit the setting of the carbons at different angles as most suited to the particular condition under consideration.

Most modern motion picture projection arc lamps are, therefore, made with carbon holders adjustable at several angles, and the rack, or main body of the lamp—to which is attached the carbon holders, is also made adjustable relative to the lamp house and the condensing lenses, permitting the operator to set his carbons at almost any desired angle in relation to each other, and, at the same time, to tilt the whole lamp body to secure the results which he may think best.

While motion picture lamps are constructed to allow for these various adjustments, there are fundamental rules governing the carbon setting which may serve as suggestions to those interested in the art. It is my intention, at this point, to impart information on this subject which will act as a guide. It is, of course, understood that the operator may find it to his advantage to slightly deviate from the main rules, because of possible difference in the carbon, the angle at which the machine is set relative to the screen, the number of amperes at the arc, etc.

Fig. 63 illustrates a direct current carbon setting having the lower carbon set straight up and down and the upper carbon inclining towards it at an angle of about 45°. This carbon setting gives, perhaps, the most satisfactory crater formation when used on direct current. The relative positions of the two carbons is ideal for maximum crater efficiency, and the lower carbon is practically out of the way, therefore not interfering with the rays from the positive crater. Many operators are using this carbon setting with great results, but it takes an expert to handle an arc with this setting, because of the fact that the upper carbon in burning away naturally moves the crater backwards, away from the lower carbon point. Within fifteen minutes' time the upper carbon crater would be much behind the point of the lower carbon unless the operator in the meantime changes the angle of the upper carbon, or through other means pushes the upper carbon forward, or tilts the lower carbon backwards so as to maintain the relative positions of the core of the upper carbon and the point of the lower carbon the same—as shown in Fig. 63. To say the least, this is a most difficult job, and therefore may be considered impractical for general purposes, although the crater efficiency is very high.

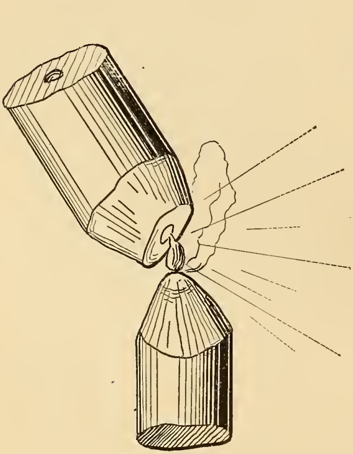


Fig. 63

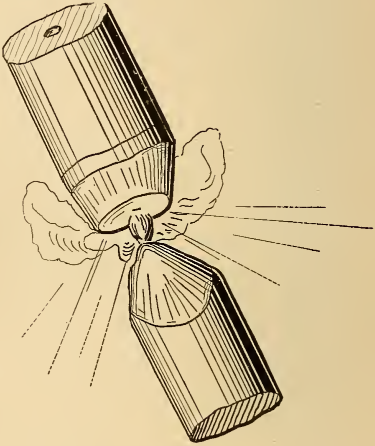


Fig. 64

In view of the trouble in obtaining constant results with the carbon setting as illustrated in Fig. 63, it has been universally agreed by operators that the best results with direct current are obtained with a soft cored carbon on the top and a solid carbon for the bottom, both carbons in practically perfect alignment.

A direct current lamp with the carbons set in perfect alignment may be tilted to any degree from the vertical position, backwards to an angle of about 45°, if necessary.

Operators sometimes find it of advantage to put the upper carbon slightly out of line, placing it a 64th or 32d of an inch behind the center line of the lower carbon. This arrangement in some instances improves the results, especially where the machine table tilts forward, as required for short projection where the screen is below the machine. Under this condition it is not always possible to tilt the lamp body sufficiently to get the proper angle on the two carbons relative to a vertical line. By putting the upper carbon slightly back of the lower one, when the lamp has to set straight up and down or tilts forward, the positive crater is coaxed forward so as to be better exposed.

Hidden Crater.—Inexperienced operators sometimes make the mistake of putting the upper carbon ahead of the lower, either by accident or on account of not knowing the harm of so doing. As a guide and illustration showing the results which follow this mistake, I submit Fig. 64, from which you will see that the positive crater actually forms on the rear side of the positive carbon, which, of course, is the side furthest away from the condensing lens. More than fifty per cent. of the illumination can be lost in this manner. There may be times when it is desirable to put the upper carbon ahead of the lower as shown in Fig. 64. As an illustration, I may mention a condition where you have to project a picture on a screen considerably higher than the machine, in which case the machine-table, lamp house and lamp would be tilted backwards. This, of course, would tilt the carbons backwards as well, and, perhaps, too much, allowing the positive crater to form too high on the front edge of the carbon, thus making the light unsteady. In such case it may be allowable to put the upper carbon ahead of the lower.

Correct D. C. Setting.—Fig. 65 illustrates what I consider the correct carbon setting and crater formation for perfect and practical direct current motion picture projection. The cut is intended to show the carbons in perfect alignment, when the lamp is tilted at an angle of 30 to 45° back of the vertical position with a practically horizontal machine table. The carbon setting in Fig. 65 is thoroughly practical and as efficient as practical results will permit. With an arc drop of 50 to 55 volts, splendid results are obtained, and by setting the lamp at the proper angle an elliptical spot can be secured on the aperture plate, which is horizontally oblong, that is, wider than it is high. This is an important point because the picture is wider than it is high, making it necessary to have, if possible, a spot which is wider than high. One often hears the expression "and I got a perfectly round 'light-spot.'" This refers, of course, to the spot of light on the shutter or on a card held in front of the aperture. A round spot for motion picture projection is not ideal. The spot which

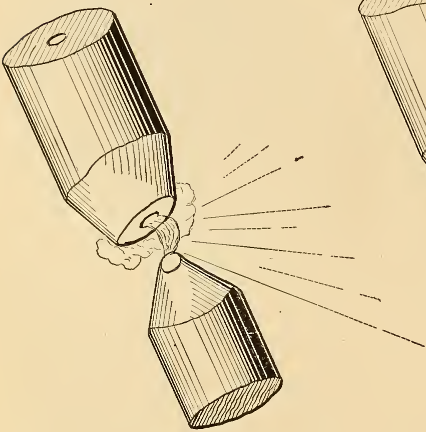


Fig. 65

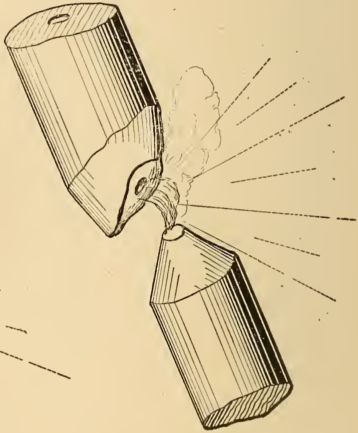


Fig. 66

is wider than it is high is preferable and more efficient, and such a spot can be obtained by setting the carbons in practically perfect alignment, as shown in Fig. 65, and can be controlled by tilting the lamp, or backward and forward adjustment of the upper carbon.

Over-prominent Crater.—Fig. 66 illustrates what may be termed a common way of setting carbons for direct current motion picture projector lamps. In this case, the upper carbon is set quite a little back of the center line of the lower carbon, and the purpose of this setting is to coax the arc forward so as to make a large and considerably slanting crater on the upper or positive carbon.

In theory this method of setting may be correct, because the crater will be more nearly parallel to the condensing lens, but under this condition we are again confronted with the difficulty of magnetic and other forces acting upon the arc, causing it to burn on the upper edge of the crater most of the time, and at other times, when the arc has burned away the upper part of the carbon, the arc may go out, or, upon feeding, it will follow the path of least resistance, which would, in that case, be the lower edge of the crater, making the light on the screen unsteady and frequently out of focus.

For good projection it is necessary to have the crater as nearly of uniform intensity over its entire area as possible. Operators will find it far better to use a small crater of great brilliancy and in a fixed position relative to the condensing lens than to use a larger crater of lower intensity and necessarily not constant, because of the fact that the arc in traveling from one part of the crater to the other makes the temperature uneven, and therefore the illumination on the screen is not uniform. Besides, the arc mist is almost altogether in front of the crater. Very little, if any, goes up on the rear side of the positive crater.

Judgment in Making Settings.—It has been previously stated that there are times when it is necessary and advisable to put the upper carbon behind the lower, especially when the front of the machine table has to be put very low or at a great angle for short projection where the screen is lower than the machine.

If you will always keep in mind the fact that the arc, being of tremendously high temperature, stimulates a considerable draft upwards, due to the difference in temperature between the air or gases immediately above and below the arc, forcing the arc towards the upper edge of the positive crater, it will be possible to somewhat limit this tendency by putting the upper carbon forward with the lower one slightly behind it. As a matter of fact, an operator can make the shape of the crater exactly as he wants it by simply shifting the upper carbon slightly relative to the lower, and I would rather advise a crater for a direct current arc like that illustrated in Fig. 65 than one like Fig. 66.

The carbon setting illustrated in Fig. 65 with carbons in perfect alignment, with the upper and lower carbons of proper proportion, that is, for instance, a ⅝-inch soft-cored carbon on top and a ½-inch solid carbon on the bottom, will allow the operator to simply feed his lamp as long as the carbons last without making it necessary to re-adjust either the lamp or carbons.

Many operators who do not use the carbon setting as shown in Fig. 65 have to frequently push or pull the carbon out of place from one position to another as the lamp continues to burn, in order to keep the crater in proper shape. All of these troubles are obviated by setting the carbons properly to begin with and by using proper carbons. It may be necessary to raise the lamp up or down slightly during the run, due to slight difference in the relative speed of the consumption of the two carbons, but with properly selected carbons even this change is not often required.

The handling of an electric projector lamp for motion pictures is not a science. If it were, anyone could operate such a lamp after reading publications on the subject or after graduating from a college or school. The manipulation of a projector arc is an art, which has to be acquired by practical experience with the aid of fundamental rules or laws as established by scientific investigation. I have met men who were posted from a scientific point of view; in other words, men who had book and school information, who could not secure results in practice with a projector arc lamp.

On the other hand, I have seen experienced operators who secured far better results on the screen without scientific knowledge of the arc. But it is equally true that these same operators after receiving technical advice and after becoming more acquainted with the various elements composing the projector arc, were able to produce still more perfect and satisfactory results.

Operators should not forget that education, as it is generally called, on specific subjects is not always intended to make one qualified to immediately perform the operation. Education is rather intended to teach the student how to use certain information and how to make himself qualified to perform by experience.

A doctor or lawyer will attend college for years. Either one may pass the college examination, but may fail utterly in practice. Therefore the personal equation enters into all kinds of work, and that is one reason why some operators of motion picture apparatus produce splendid results with even inferior devices, whereas others are not able to produce satisfactory results at all with the best equipment.

Municipal authorities all over the country, on account of fire risk, have issued new and drastic rules, and are enforcing a system of examination of operators in order to make exhibitions safe. Operators should encourage examinations of this sort rather than oppose them, because it will ultimately weed out the element among them incapable of properly operating a machine and unable to project a good picture. In the larger cities in particular, these examinations are strict. An operator in most cities does not get a license as a qualified operator until he has passed an examination which may consist of questions relative to his knowledge of the electrical part of the equipment as well as a full understanding of the motion picture machine. Besides, it is in many cases required that he shall have had practical experience as assistant to a qualified, licensed operator for a considerable period. I believe all beginners should be compelled to serve for at least six months, working under an experienced operator during that time, just the same as apprentices have to do in any other trade or profession. It will help to raise the standard of the profession; it will be the means of an ultimate increase of the salary of the operators at large, because there will be less competition from poor and inexperienced men, and managers getting better results will be glad to pay higher salaries to operators.

It is not my intention in this work to dictate to the operator. The information which I impart is to guide him in securing better results.

Settings for Tilted Projectors.—The operator should be prepared to meet abnormal conditions where the machine-table, lamp house, lamp and machine must be placed at a considerable angle above or below the horizontal position. The following suggestions may guide the operator in securing better results.

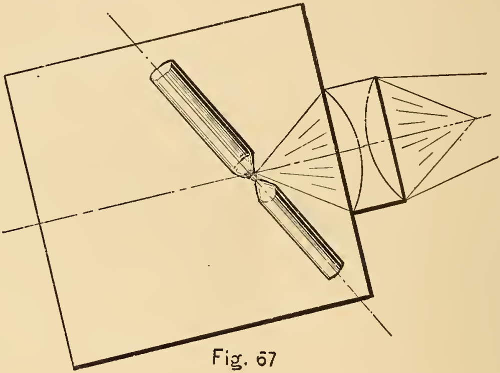


Fig. 67

In order to make this matter more clear, I submit Fig. 67, illustrating a lamp house with lamp tilted backwards to project a picture on a screen considerably higher than the machine. This arrangement may be necessary in large theaters where the operating room is placed below a balcony, or in the rear on the main floor, or in places where the floor does not incline and where it is therefore necessary to place the curtain above the machine.

It is evident that with this arrangement the ordinary slant of the carbons will be considerably increased by the raising of the front of the lamp house, and therefore if the carbons are set in perfect alignment, the crater on the positive carbon would be forced upwards, making the crater long and difficult to control. Under a condition of this sort it is advisable to put the center line of the upper carbon slightly ahead of the center line of the lower carbon, as illustrated in Fig. 64. Please note, however, that the crater will not form as in Fig. 64, but, due to the lamp and carbons being tilted backwards, it will form higher up, approximately like illustration Fig. 65, which is a correct representation of how the crater should look.

For normal projection where the center of the screen is on a level with the projecting lens, the carbon should be set as illustrated in Fig. 68, which is practically the

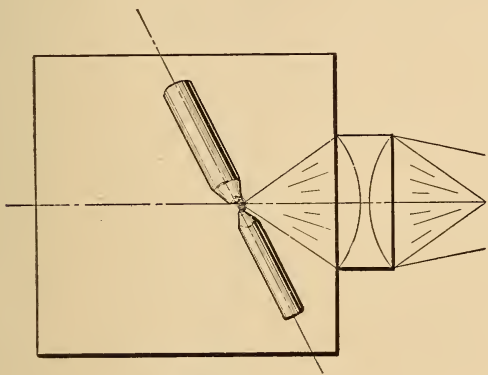


Fig. 68

same setting as shown in Fig. 65, which represents the proper crater formation for such projection. This setting may be considered the best for direct current for general purposes.

There are, however, other conditions to meet. For instance, where the machine is placed considerably higher than the screen, as would be the case in a regular theater where it is necessary to place the machine in the front of the balcony. Under this condition the machine is much higher than the screen, making it necessary to tilt the table, lamp house, and machine forward to a considerable degree, as illustrated in Fig. 69. Under this condition the angle at which the carbons are put, in relation to the vertical or plumb line, is considerably decreased; as a matter of fact, the placing of the machine in this position may put the carbons in a perfectly vertical position, which, of course, is not right for direct current. In order to coax the arc forward, it will be necessary to put the upper carbon slightly behind the lower, something like the illustration shown in Fig. 66.

This matter of adjusting the carbons for different machine positions is of considerable importance, and it is evident that no universal rule can be applied, but by following the foregoing suggestions an operator can secure the best results possible for any given installation.

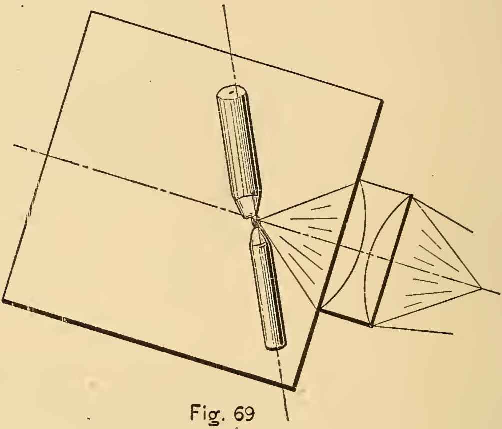


Fig. 69

For advertising purposes it is sometimes necessary to put the projector in a position where it will show a picture immediately below the machine or stereopticon. For instance, if it should be required to throw a picture on a sidewalk, then the lamp would have to set with the condensing lenses facing down, as illustrated in Fig. 70. With the lamp-house set in this position we could utilize the right angle carbon setting as illustrated in Fig. 62 to good advantage.

Under other conditions it may be necessary to project the picture on the ceiling of a high building, in which case the lamp-house would be turned so that the condensers would be on top. With the lamp-house set in this position a carbon setting as illustrated in Fig. 71 will perhaps serve best.

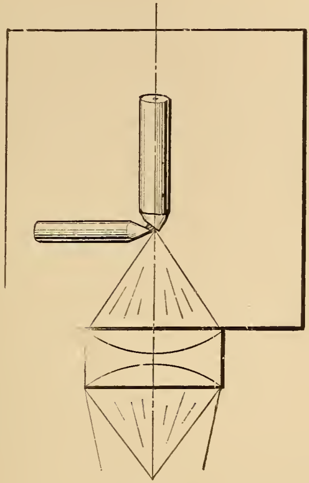


Fig. 70

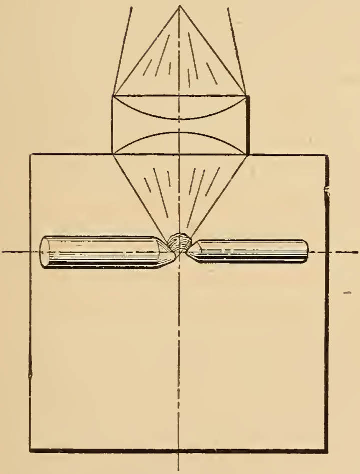


Fig. 71

The conditions referred to, and illustrations Figs. 70 and 71, are remote and unusual, and could be taken care of by using reflecting mirrors, or glass prisms, but I thought it best to include them while discussing the direct current projector arc.

I would advise operators who may read the foregoing, who have at their disposal a direct current supply and a projector lamp, to try the various carbon settings referred to and observe the results. It will pay any operator to practice along these lines, as familiarity with the different results obtained will soon make him expert in this matter.

> Taking all of the foregoing into consideration it appears that the carbons for a direct current projector lamp should be in practically perfect alignment with each other, although in some instances the upper carbon may be put slightly forward and in other instances slightly back of the lower carbon. It is not advisable to put the two carbons at an angle relative to each other, because of the necessity of constantly having to readjust the carbons in addition to feeding them.

CHAPTER VII

Resistance

THEORY

BEFORE proceeding with a detailed discussion of the subjects under this heading, I wish to present a definition of the term "resistance" by Dr. T. O'Connor Sloane:

Resistance is the quality of an electric conductor, in virtue of which it opposes the passage of an electric current, causing the disappearance of electro-motive-force if a current passes through it, and converting electric energy into heat energy in the passage of a current through it. If a current passes through a conductor of uniform resistance there is a uniform fall of potential all along its length. If (the conductor is) of uneven resistance, the fall in potential varies with the resistance. The fall of potential is thus expressed by Daniell:

In a conductor, say a wire, along which a current is steadily and uniformly passing, there is no internal accumulation of electricity, no density of internal distribution (meaning that the center of a solid wire could be removed without decreasing the conductivity to any great extent.—Ed.), there is, on the other hand, an unequally distributed charge of electricity on the surface of the wire, which results in a potential diminishing within the wire from one end of the wire to the other.

Resistance varies inversely with the cross section of a cylindrical or prismatic conductor, in general with the average cross-section of any conductor, and in the same sense directly with its true or average or virtual length. It varies for different substances, and for different conditions, as of temperature and pressure for the same substance. A rise of temperature in metals increases the resistance, in some bad conductors, a rise of temperature decreases the resistance. Approximately, with the exception of iron and mercury, the resistance of a metallic conductor varies with the absolute temperature. This is very roughly approximate.

Except for resistance, energy would not be expended in maintaining a current through a circuit. The resistance of a conductor may be supposed to have its seat and cause in the jumps from molecule to molecule, which the current has to take in going through it. If so, a current confined to a molecule would, if once started, persist because there would be no resistance in a molecule. Hence on this theory the Amperian currents would require no energy for their maintenance and Ampere's theory would become a possible truth.

When metals melt, their resistance suddenly increases.

Light rays falling on some substances, notably selenium, *q. v.*, vary the resistance.

Longitudinal stretching of a conductor decreases the resistance; but increases it with longitudinal compression, and increases in iron and diminishes in tin and zinc when a transverse stress tends to widen the conductor.

The term "resistance" is used to express any object or conductor used in circuit to develop resistance.

The foregoing theory and explanation of the word "resistance" should be studied very carefully in order that you may form a clear and thorough understanding of what really takes place in an electric conductor under different conditions when it forms the part of an electric circuit.

Different metals offer different degrees of resistance, and it is interesting to know and well to remember that all electric conductors of ordinary resistance increase in resistance as the temperature is increased.

You know that whenever an electric current passes through a conductor there is a certain amount of loss, due to the resistance of the conductor, and that this loss manifests itself in the shape of heat.

With this fact established in your mind, you can put two and two together and will understand that the more current you crowd through a normal or ordinary conductor, the greater will be the heat generated in such conductor, and consequently there will also be an increase in the resistance of the conductor, and the tendency or effect is to lower the voltage, or potential, at the end of the conductor.

You will also find from the foregoing explanation of the term "resistance" that there are some bad conductors which work in the opposite direction, inasmuch as the resistance of some such bad conductors will actually decrease as the temperature increases, and among such bad conductors I may mention, as a practical example, the "glower" (a secret mineral composition) as used in the Nernst lamp. The ingredients of the Nernst glower are not generally known, but are made by pressing through a die, a dough composed of the oxides of the rare earths, mixed with a suitable binding material. The porcelain-like string thus formed, is cut, after drying, into convenient lengths. It is then baked, and terminals are attached by means of which a current of electricity may be passed through the glower. For the benefit of those who don't know, I will mention that the glower in a Nernst lamp, when cold, is an insulator to very high voltage electric current, but after it becomes heated by a match, alcohol lamp, or by a small red-hot resistance wire or heater, it gradually becomes a conductor, of high resistance at first; then as the current begins to pass through the glower it heats itself, and in a few moments its temperature increases so that it glows at white heat, and it would melt, and consequently destroy itself as the resistance becomes so low at the higher temperature that it would simply burn itself in two. The reference to this glower is very interesting and instructive, because its action is just opposite to that of the regular resistance wire, which increases in resistance the higher the temperature at which it is operated. For this reason a Nernst glower, in order to be made practical, has to have a "ballast" or steadying or limiting resistance, as we may call it, connected in series with the glower. This "ballast" is usually made from a material which increases rapidly in temperature, and offers a much greater resistance when it becomes heated. The glower and the "ballast" resistance act exactly opposite to each other, admitting, therefore, a steady flow of amperes through the "ballast" and glower circuit which is then maintained at an automatic balance.

Now we will use the electric arc in place of the glower. Its action, as far as resistance is concerned, is practically the same as that of the glower, inasmuch as the resistance of the arc when maintained at a constant length, or at a given carbon separation, will decrease as the amperes increase, therefore constantly decreasing the limit of current which can flow between the two carbon points, unless some other element is introduced to counterbalance this effect, or, in other words, put a check or limit on the current flow. The element which in practice is used for this purpose in connection with projector arc lamps, is the resistance or rheostat, as it is usually called. For the purpose of checking the current in series with the arc, a rheostat composed or made of a material which will increase in resistance as the temperature of the resistance, or wire is increased. For a better understanding of the foregoing references I refer you to the accompanying illustrations.

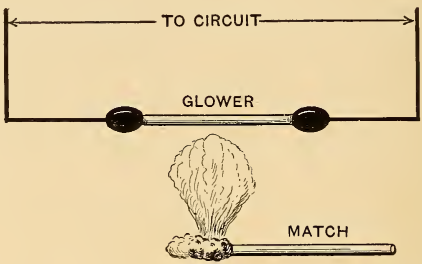


Fig. 72

Fig. 72 shows a Nernst lamp glower connected to an electric circuit with a lighted match below it, the flame of which heats the glower so that it becomes a conductor, and

Fig. 73 shows the glower in operation, in which condition it would last only a second, because the current will crowd through it more and more, the hotter it gets, burning it

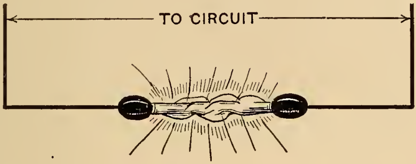


Fig. 73

out as shown in illustration Fig. 74. The correct method of operation, in order to prevent the glower from admitting too much current, is to connect a "ballast" or a re-

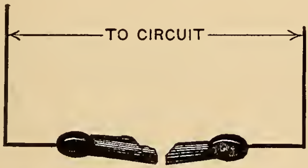


Fig. 74

sistance in series with the glower as illustrated in Fig. 75. In this instance the "ballast" is enclosed in a vacuum within a glass bulb, and the ballast wire, which is made of a material like iron, operates at red heat.

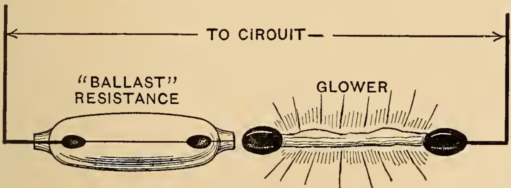


Fig. 75

Fig. 76 shows almost the duplicate condition of the Nernst glower in which the arc between two carbon

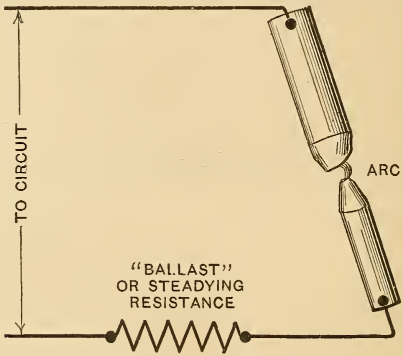


Fig. 76

points is the equivalent to the glower and the steadying resistance or ballast is connected in series with the arc the same as required in the Nernst glower.

PRACTICE

The subject of the regulating resistance in conjunction with the electric arc is so important that in order to fully understand its functions the reader should thoroughly instill into his mind the following extremely important facts before proceeding any further:

> The electric arc introduces a given drop of potential for a given separation of the carbon points and for a specified ampere flow.
>
> Should the current flowing through the arc be decreased in amperes and the carbon separation reremain the same, the potential drop across the arc will increase.
>
> Should the current flowing through the arc be increased in amperes and the carbon separation remain the same, the potential drop across the arc will be decreased.

From this you will learn that the arc is not self-regulating. As a matter of fact its resistance decreases as the current is increased, therefore there is practically no limit to the amount of amperes which can flow over an arc between two carbons connected directly to a constant potential circuit, as far as the arc is concerned.

The direct current projector arc lamp, as has already been stated, requires between 45 and 55 volts at the arc. On account of the arc not being self-regulating, but rather of decreasing resistance with increased flow of current, it becomes necessary on regular multiple lighting circuits to introduce a resistance of some sort connected in series with the arc to limit the current flow.

The resistance required to limit the current flow and to regulate the arc may be called "steadying resistance" or "ballast."

> Experience proves that the "ballast" must be equal to at least 25 per cent. of the arc voltage.

If we consider a projecting arc operating with a potential drop of 50 volts, the necessary potential drop across the "steadying resistance" or "ballast" in series with the arc must be 25 per cent. of 50 or 12.5 volts, which would make the required voltage for the satisfactory operation of the lamp about 62.5 volts.

Many attempts have been made to operate a 50-volt arc lamp on a 50-volt constant potential dynamo without any resistance in series with the arc, but this method of operation is impossible.

> The lowest voltage constant potential circuit on which a direct current projector arc can be maintained in satisfactory operation is 60 volts, but this voltage is really too low, and for safe operation it is far better to allow a greater margin of voltage for the "steadying resistance" or "ballast"; in fact, 70 to 75 volts on the line giving 20 to 25 volts drop in the "steadying resistance" will give better results.

It is a well-known fact that standard electrical distribution systems are not available giving 70 to 75 volts, therefore it becomes necessary to operate motion picture projector arcs on the standard systems which generally supply either 110 or 220 volts, which, of course, requires a greater amount of resistance in series with the arc.

The steadying resistance must be equal to at least 25 per cent. of the arc voltage, and also that it is better to allow even greater potential drop in the steadying resistance, going posibly as high as 40 to 50 per cent. for very best results.

Suppose, for the sake of argument, that we allow 50 volts at the arc and 20 volts for the steadying resistance; this makes a total of 70 volts actually required. If we have constant potential direct current at 70 volts, we have the ideal current supply for a direct current projector arc lamp.

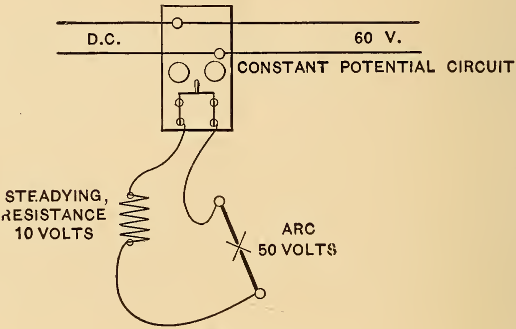


Fig. 77

The standard lighting circuits, however, as already stated, are maintained at 110 and 220 volts; therefore we must take care of the difference in voltage between 70 actually required, and the line voltage, which we will say is 110, making a voltage drop of 40 volts. This extra voltage must be taken care of by a resistance offering a potential drop of 40 volts at the required amperes, and we may call this part of the resistance the "reducing resistance," because this part of the voltage is not necessarily required, and must simply be disposed of or used up in a resistance and is a dead loss.

For 60 Volts.—For a better understanding of the foregoing I offer, as an additional explanation, Fig. 77, illustrating the application of the electric projector arc to a direct current constant potential circuit of minimum, allowable line voltage, which as illustrated and referred to is 60 volts.

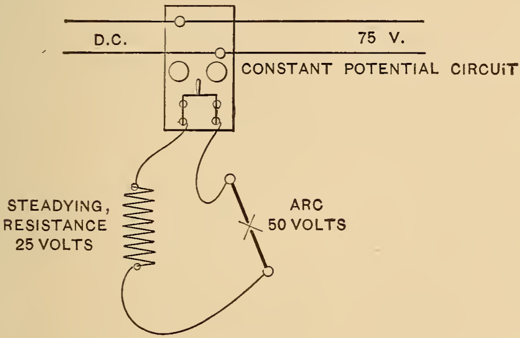


Fig. 78

For 75 Volts.—Fig. 78 illustrates the application of the projector arc to a 75-volt direct current constant potential circuit, which is the ideal condition of operation where the arc is to be controlled by a steadying resistance or "ballast."

For 110 Volts.—Fig. 79 illustrates the application of the projector arc to a standard 110-volt constant potential circuit, and the illustration shows the steadying resistance and reducing resistance combined as is the usual method of operation where projector arcs are controlled by resistance in series with the arc.

For 220 Volts.—There are, however, other conditions to be met where the voltage is greater than 110. For instance, in some cities where only 220 volts can be had for the operation of motion picture projector lamps. In such a case the reducing resistance combined with the steadying resistance or ballast becomes a large unit which has to introduce a potential drop of 170 volts, because of the fact that the arc requires only 50 volts. Fig. 80 shows the voltage drop in the different sections of the circuit.

For 550 Volts.—In amusement parks and some towns it is sometimes necessary to operate the projector arc on a street railway or power circuit supplying from 500 to 600 volts. With this high voltage the reducing re-

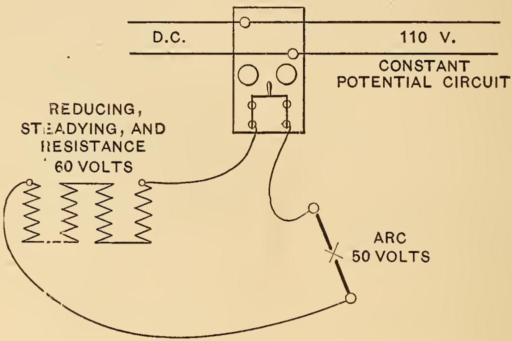


Fig. 79

sistance becomes very large, and as the arc requires the same drop, namely, 50 volts, it is evident that about 500 volts has to be consumed in the reducing and steadying

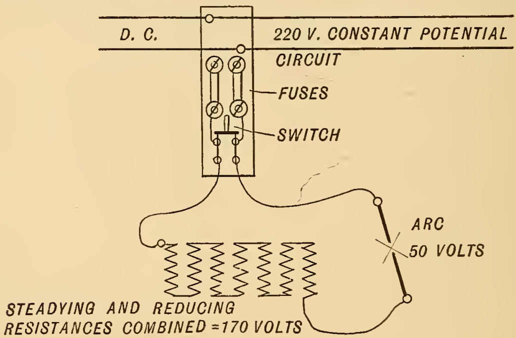


Fig. 80

resistance. Fig. 81 illustrates such a connection and system.

Arc Voltage Limit.—It would seem that where the line voltage is so high it would be practical to use a higher voltage at the arc so as to employ some of the energy to increase the illumination instead of wasting it in the reducing resistance. Previous information on this subject has made you acquainted with the fact that it is not practical under any condition to use more than 60 volts at the arc because at this point the arc begins to flame excessively. As a matter of fact, 55 volts is about

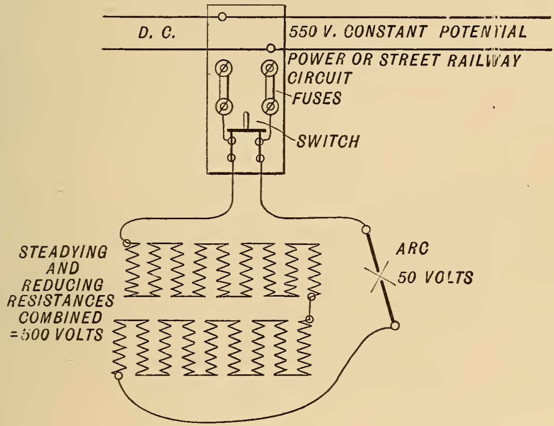


Fig. 81

as high pressure as can practically be used to advantage at the arc, and a drop of 50 volts is the ideal pressure at which a direct current projector arc should operate.

The resistance of a projector arc circuit is, in accordance with the foregoing, composed of three parts:

First—The drop across the arc, which is usually 50 volts.

Second—The drop across the steadying resistance or ballast in series with the arc, which must not be less than 10 volts and need not be more than 25 volts.

Third—The drop across the reducing resistance which depends entirely upon the voltage of the supply circuit being approximately as follows: 40 volts on 110-volt circuit, 150 volts on 220-volt circuit, 480 volts on 550-volt circuit.

Calculating Resistance.—On pages 20, 21 and 22 are given formulae Nos. 1, 2, 3 and 4, by means of which you may calculate the amount of ohms required for different conditions. Formula No. 4 also permits you to calculate the watts expended in the arc as well as the watts expended in any portion of the resistance connected in series with the arc.

To refresh your memory, I will offer the following problems:

PROBLEM 1

Suppose we have a constant potential 110-volt direct current circuit upon which it is desired to operate a projector arc lamp with 30 amperes at the arc—find the total number of ohms required for the steadying and reducing resistance combined.

Solution of Problem 1.—Line voltage 110 — arc voltage 50 = 60 volts, which is the potential drop across the total resistance in series with the arc.

Formula No. 2 reads, $R = \frac{E}{C}$, or in simplified form, resistance in ohms equals 60 volts divided by 30 amperes equals 2 ohms.

PROBLEM 2

The same as Problem No. 1, but in this case the line voltage is 220.

Solution of Problem 2.—Line voltage 220 — arc voltage 50 = 170 volts, which is the total drop in the steadying and reducing resistance, in series with the arc. Using again Formula No. 2 (page 21), we find resistance in ohms equals 170 divided by 30 amperes, 5⅔ ohms.

PROBLEM 3

Find the number of watts required per hour for a 30-ampere projector arc lamp on 110-volt direct current circuit.

Solution of Problem 3.—Total line voltage 110, total amperes 30, Formula No. 4 reads, $W = C \times E$; in other words, watts equal 30 amperes times 110 volts or 3,300 watts or 3.3 kilowatts per hour.

PROBLEM 4

Find the number of watts expended in the arc (only) of a projector lamp operating at 50 volts with a current flow of 30 amperes.

Solution of Problem 4.—Watts = 30 amperes × 50 volts or 1,500 watts, or 1.5 kilowatts per hour.

PROBLEM 5

Find the number of watts lost in the resistance connected in series with a 50-volt 30-ampere projector arc lamp on 110-volt direct current circuit.

Solution of Problem 5.—The voltage drop across the total resistance in series with a direct current projector arc, on 110 volts, we have previously found to be 60; using again Formula No. 4, we find that watts expended equal 30 amperes × 60 volts, which equals 1,800 watts or 1.8 kilowatts per hour.

This last example is interesting in comparison because it proves to you that of the total 3.3 kilowatts required from the line only 1.5 kilowatts is made use of at the arc; the balance, which is the greater part representing the 1.8 kilowatts, is lost in the shape of heat in the resistance.

There are several methods which can be employed for the purpose of reducing the line voltage to the proper amount required for the control of a projector arc lamp on direct current, and we will discuss, in the chapters following, these various methods.

Considering previous references to the direct current projector arc, we have established the fact that

> the electric arc does not put a limit on the amount of current which can be carried by it. As a matter

of fact, the resistance of the arc decreases as the temperature increases.

Therefore, permitting a continually increasing amount of amperes to flow over the arc, up to the capacity limit of the conductors and generators which supply the current. We have determined that the direct current projector arc is most efficient with a potential drop of about 50 volts, and that, in order to limit or regulate the amount of current flowing across the arc, a given amount of ballast or steadying resistance must be connected in series with the arc. The potential drop across this ballast or steadying resistance must be at least 25 per cent. of the arc voltage, which would make the minimum voltage upon which a direct current projector arc may be operated, between 60 and 65 volts. We know that the potential—usually supplied by the ordinary electric systems—varies between 100 and 60 volts, and we have also calculated the various amounts of resistance required in series with projector arc lamps on different voltages.

CHAPTER VIII

The Rheostat

THE RHEOSTAT is a device to be connected in series with an electric arc, and its purpose is:

First: To reduce the line voltage.

Second: To introduce the necessary steadying effect, in order that the arc may be maintained with normal current flow.

The rheostat is usually composed of a wire, mounted on an insulating frame, beginning at one terminal of the rheostat, the other end being connected to a second terminal. There are many different kinds of rheostats, employing many kinds of wire, made up in hundreds of ways, to suit the ideas of each individual manufacturer.

There are four essential points, however, which govern the designer of rheostats:

First: The temperature of the resistance unit must not be so high as to cause excessive depreciation of the resistance medium or wire.

Second: The construction must be such, that continued expansion and contraction will not loosen the clamps which hold the various sections of the resistance unit in contact with each other.

Third: There should be a fairly large space between the resistance unit, and the metal parts, which form the frame and the metal casing surrounding the unit so as to prevent excessive heating of the external metal parts.

Fourth: Only porcelain, mica and asbestos or other similar non-combustible materials should be used for the insulation of the various supports and terminals in a rheostat.

The resistance for an arc lamp must be of the kind which will increase with an increase of current flow, and consequent temperature rise. It has been found that iron or steel wire possess this quality. For practical purposes, however, the pure iron or steel wire, is not of sufficiently high resistance; therefore, it is customary to use a wire made from a special alloy, composed of steel and nickel which increases the resistance to a considerable extent, thereby reducing the length of wire required, which at the same time, of course, reduces the over all dimensions of the frame and rheostat casing.

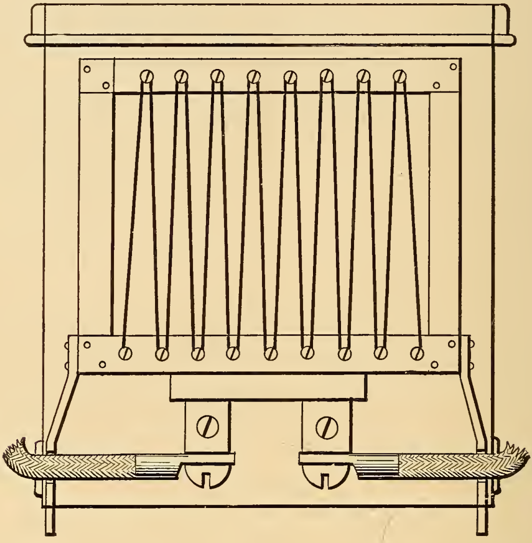


Fig. 82

For the highest class of rheostats, a special wire made from an alloy composed mainly of nickel and copper is sometimes used. The object in using nickel copper wire is to prevent rust, especially where the rheostat is used outdoors, or transported from place to place where it would be likely to be subjected to severe weather conditions, and consequent unusual and rapid temperature change.

Non-Adjustable Type.—Fig. 82 illustrates a rheostat having the resistance unit composed of a resistance wire mounted in zigzag form on small insulating buttons, supported by a suitable metal frame, enclosed in a ventilated metal case. The illustration shows the beginning and end of the resistance wire attached to proper binding posts or terminals supported on an insulating block or base. The metal casing is generally made of perforated sheet-iron, aluminum or brass and this cover or protecting case must entirely enclose the resistance unit and terminals and

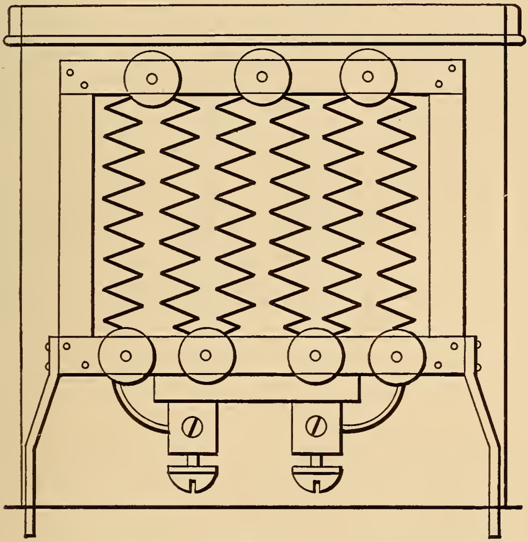


Fig. 83

suitable openings with proper bushings should be provided in the metal case, through which the asbestos covered copper cables may enter for making connection with the binding posts. It is evident with such a rheostat as described in the illustration, if the proper size wire is used, would be absolutely fireproof and almost indestructible and the great advantage of this particular type of rheostat is due to the fact that the resistance wire is continuous from one end to the other without a break.

Fig. 83 illustrates a similar type of rheostat, which is, however, somewhat simpler in construction, in that it requires a lesser number of insulating supports which is accomplished by winding the resistance wire on an arbor in the form of a spiral, so as to make the resistance unit more compact. This form of resistance unit can, of course, not be operated at as high a temperature as the design illustrated in Fig. 82 on account of the possible sagging of the spirals, as the wire loses its temper when heated excessively. The spiral form of resistance is, however, the type generally used and if not overloaded gives excellent satisfaction. Fig. 83 shows also a continuous wire without a break. For convenience of manufacture, a resistance unit is generally made in several short spirals which are connected together at each end so as to form a continuous series circuit—from one end to the other. This form of construction, in sections, is not as good as the continuous construction illustrated in Fig. 83, on account of the possibility of loose contact between some of the units, but if carefully designed and constructed, the possibility of trouble on this account can be almost entirely eliminated.

For the control of street railway motors, and for the field control of large generators, there has been used, for some years, a rheostat made up from cast-iron grids or plates, of zigzag form which are mounted so as to furnish a continuous strip of cast-iron in series with the electric circuit. Where the rheostat is not subjected to excessive vibration or jar, this form of construction is very desirable and satisfactory. The "grid" type resistance is now also used for the control of projector arc lamps, and is sometimes preferred to the wire rheostat because it will stand a heavier or greater overload, and is of very solid construction. The grid type rheostat should be examined at frequent intervals in order to make sure that the bolts or clamps, which connect the resistance plates together, have not become loosened—due to frequent expansions and contraction.

The rheostats so far mentioned, are of the non-adjustable type. Under certain conditions it is necessary to use an adjustable rheostat, in which case, a switch arm, making contact with a number of buttons connected to different sections of the rheostat has to be used. Fig. 84 illustrates an adjustable rheostat in diagrammatic form.

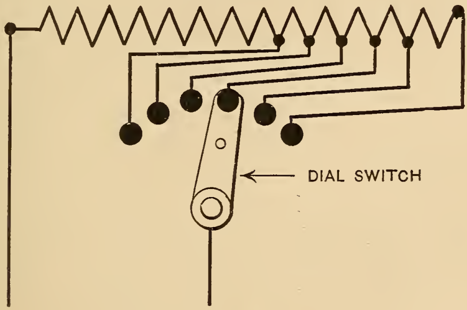


Fig. 84

Adjustable Type.—Fig. 84 illustrates the principle on which an adjustable rheostat works. By referring to the diagram, it will be seen that the entire resistance unit, which may be of any type desired, is stretched out or mounted in suitable manner. The beginning end may be attached to one line wire, the other end to a contact button or contact plate, which forms the last step of an adjustable or dial switch. Several additional buttons may be provided, each one being connected with some intermediate point on the resistance unit. The distance between these points determines the difference in voltage drop between each contact button on the dial switch which, of course, increases the flow of amperes through the rheostat as the dial switch is swung to the left, cutting out sections of the resistance unit in series with the arc. One lead from the arc lamp is connected to the lever of the dial switch, and the other arc lamp lead, not illustrated, is connected to the second line wire, forming a complete series circuit from the first line wire through whatever portion of the rheostat may be in series with the dial switch, through the arc lamp back to the line.

Fig. 84 shows the simplest form of adjustable rheostat and the cheapest to manufacture. For special purposes, however, more elaborate adjustable rheostats can be made and as a simple illustration, I call your attention to Fig. 85, in which the rheostat is composed of several independ-

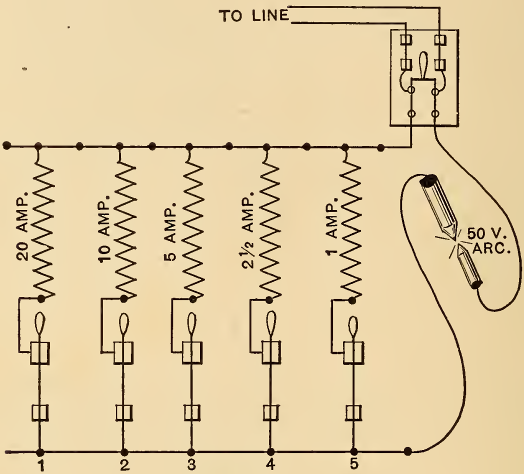


Fig. 85

ent spiral resistance units all connected together at the top, but the lower ends are connected to independent single pole switches. The switches are, however, connected together at the lower end. An examination of this arrangement will prove to you that if the connections are made as illustrated in Fig. 85, and all switches are closed, the rheostat offers the lowest amount of resistance and allows the greatest number of amperes to flow over the arc because the entire number of resistance units are connected in parallel or multiple.

Let us assume, as an example, that each one of the resistance spirals allows a current flow of 10 amperes with a given line voltage and that the potential drop at the arc is just 50 volts, then the current flow over the arc will be as follows:

With Switch No. 1 closed...........10 amperes
With 1 and 2 closed.................20 amperes
With 1, 2 and 3 closed...............30 amperes
With 1, 2, 3 and 4 closed............40 amperes
With all switches closed.............60 amperes

You will appreciate the great advantage of rheostats constructed on this plan because each resistance unit is absolutely independent of any of the others, and in case one unit should become disabled, it does not prevent you from operating the rheostat, although with slightly lower current flow.

Rheostats built on the principle illustrated in Fig. 85, can also be made in sub-divided sections so as to permit each half to be connected in series for 220 volts and in parallel for 110 volts.

It is also evident that any one of the resistance units illustrated in Fig. 85, can be made in any desired capacity. For instance:

Unit No. 1 can be made to allow a current flow of 20 amperes,
Unit No. 2, 10 amperes,
Unit No. 3, 5 amperes,
Unit No. 4, 2½ amperes,
Unit No. 5, 1 ampere,

giving a most perfect control of the current flow through the arc.

If all switches are open and you close switch No. 3, the arc would operate at 5 amperes. If switch No. 2 is closed and all other switches open, the current flow will be 10 amperes. If switches 2 and 3 are closed, the current flow will be 15 amperes. If we also close switch No. 1, the current flow will be 35 amperes and so on, depending upon the number of switches that are closed.

For regular motion picture projector arc lamps, the type of rheostat, illustrated in Fig. 85, is not necessary, because the voltage supply is generally constant and operating conditions do not vary to any great extent. A fixed non-adjustable rheostat is always preferable where an adjustable type is not necessary.

For the traveling show, however, an adjustable rheostat constructed along the lines as illustrated in Fig. 85 is very desirable, especially if the design is elaborate as in Fig. 86, which shows a complete interchangeable unit for 110 or 220-volt line having any ampere output desired, depending upon the size of the different resistance units. When using the design shown in Fig. 86, it is important

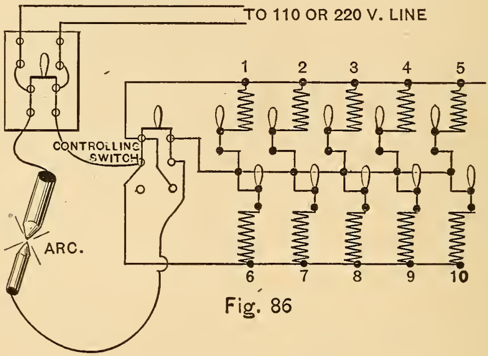


Fig. 86

that all resistance units be made to pass the same number of amperes unless the operator practices care in closing only corresponding switches on each side of the rheostat, in which case it is permissible to make the resistance units of different degrees of resistance and capacity to allow for a varying flow of amperes.

In explanation of the foregoing statement, I may say that if, in Fig. 86, resistance No. 1 is of the same capacity as No. 6, these two switches may be closed, allowing the two resistance units to operate either in series or parallel, depending upon the position of the controlling switch. If the controlling switch is in the upper position as shown, the resistance units will operate in parallel, which is more clearly illustrated in Fig. 87.

If the controlling switch is closed in the lower position the resistance units will operate in series as is more clearly illustrated in Fig. 88.

Again referring to the operation of this form of rheostat with unequal resistance units I may say that if resistance No. 3 in Fig. 86 is made for 5 amperes, and resistance unit No. 10 is made for only one ampere, it would not do to leave only these two switches closed when the rheostat is to be used in series on 220-volt line as the two units on opposite sides must be of the same ampere capacity, and therefore, if No. 8 resistance unit is of 5 ampere capacity it should always be in series with No. 3, which is also of 5 ampere capacity.

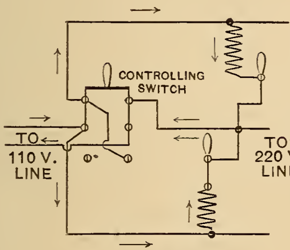


Fig. 87

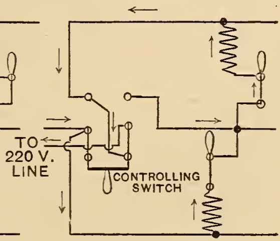


Fig. 88

METHODS OF CONNECTING

When using the term "rheostat" we naturally refer to a resistance box, within which is contained one or more resistance units of either the non-adjustable or adjustable type. On page 148 you were advised how, within one resistance box or rheostat, several resistance units of like or unlike capacity can be combined and by the manipulation of switches, almost any degree of current strength can be obtained for either series or parallel (or, as it is also called, multiple) connection.

Before proceeding further I want to state that the same rheostat may be used for either a. c. or d. c., but it must be remembered that a given rheostat will pass from ten to twenty per cent. more amperes when used on a. c. This is providing the line voltage is the same for both currents. The increased current is due to the fact that the a. c. arc gives best results at 35 volts as compared with the d. c. arc at 50 volts.

Single Multiple.—Fig. 89 is a diagrammatic illustration of an ordinary 25-ampere rheostat for a 50-volt projector arc lamp operating on 110-volt line. This rheostat

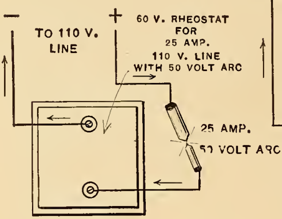


Fig. 89

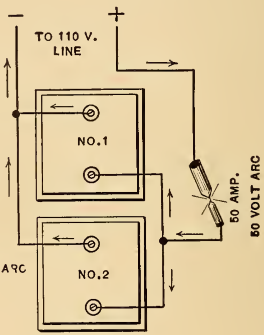


Fig. 90

is of the same design and construction as illustration Fig. 83, and is the type generally furnished with motion picture machines.

Double Multiple.—There are conditions under which it is necessary to have a greater amount of amperes. For instance, where alternating current is used, because of the fact that with the a. c. arc the upper and lower carbon craters are both of the same intensity, or light giving quality and, as a general rule, with the ordinary angle carbon setting, only one of the craters can be focused. Also, for long projection, that is to say, where the distance is more than 80 feet or where a picture is considerably larger than 12 feet wide, and in other places where a brilliant picture is required, it becomes necessary to increase the current flow at the arc. The increase in amperes at the arc can, of course, be had by installing a specially constructed rheostat to pass a greater amount of current. There are, however, cases where a special rheostat is not available, and under such conditions it is possible to combine two or more ordinary rheostats, which may be connected in parallel or multiple. Fig. 90 shows two ordinary 25-ampere, 110-volt rheostats connected in multiple for the control of one projector arc lamp, which under this condition will operate with about 50 amperes at the arc.

It is evident, of course, that it is possible to use 110-volt rheostats of different amperes in parallel or multiple, as illustrated in Fig. 90, and as an illustration, I may say, that rheostat No. 1 might be of 25 amperes capacity, and rheostat No. 2 of 10 amperes capacity, under which condition the arc would not receive 50 amperes, but the sum of 25 and 10, which is 35 amperes. Anyone interested in the art can understand how almost any combination can be obtained, and all that is necessary to keep in mind is the fact that whenever rheostats are used in a parallel or multiple combination, each individual rheostat must be constructed for the operation of a projector arc lamp on 110 volts. In other words, the potential drop across each rheostat, with the specified amount of amperes which it will safely carry, must be the difference between the line voltage, which is 110 and the arc voltage which should average 50, leaving a balance of 60 volts as representing the potential drop across each rheostat.

Triple Multiple.—It may, under some conditions be necessary to use as much as 75 amperes at the arc which, by the way, is customary in several countries where the projection is long, the pictures are large and where extremely brilliant pictures are required. In cases of this sort, three ordinary 25-ampere rheostats may be connected in multiple if one specially constructed 75-ampere rheostat is not available. Fig. 91 shows such a connection.

Where 220-volt circuits are to be considered, the same arrangement, as illustrated in Figs. 89, 90, 91 can be applied, providing, of course, that each individual rheostat is made for operation on 220 volts instead of for 110 volts as illustrated.

Series for 220 Volts.—Where specially constructed, 220-volt rheostats are not at hand, ordinary 110-volt rheostats may be combined to answer the purpose by properly connecting them. It will not do, as a general rule, to connect two ordinary 110-volt rheostats in series for 220 volts—excepting in case of an emergency, because if the rheostats are constructed for 25 amperes and each one offers a potential drop of 60 volts, together with the

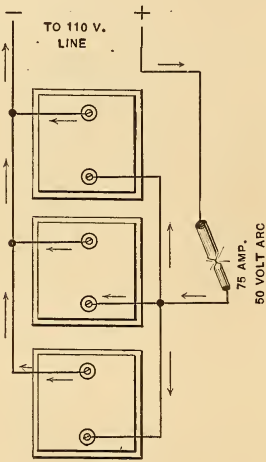


Fig. 91

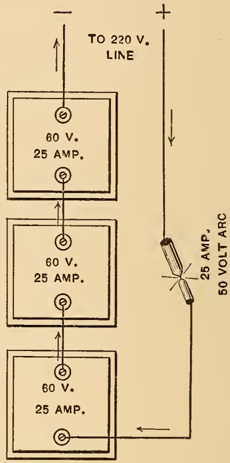


Fig. 92

arc offering a drop of 50 volts, the total drop across the two rheostats in series, and the arc, equals only 170 volts, whereas, the line is 220, which leaves a balance of 50 volts higher potential than ordinarily considered safe for two such rheostats controlling one 50-volt arc. The result is an increase of current, unless another rheostat offering an additional drop of 50 volts is introduced in series with the two other rheostats, and the arc, as illustrated in Fig. 92.

Fig. 92 shows a slight discrepancy as compared with the above figures, because for convenience I use three 110-volt 25-ampere rheostats, each one offering a drop of 60 volts, whereas one should have a small part cut out, so as to offer a drop of only 50 volts, in order to make the circuit balance at exactly 25 amperes, but in practice this difference is not large enough to be of much account. However, those who wish to maintain the arc at full 25 amperes with 50 volts, may cut out about 20 per cent. of the resistance units in one of the rheostats.

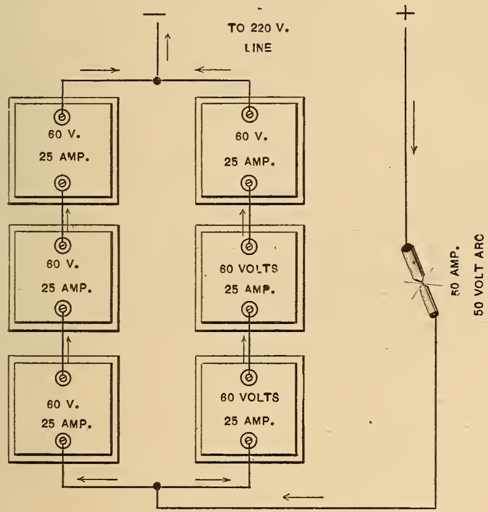


Fig. 93

Multiple Series for 220 Volts.—Fig. 93 illustrates six ordinary 110-volt, 25-ampere rheostats connected, in multiple-series where 50 amperes at the arc is necessary when operating on 220-volt line, and where only ordinary 110-volt rheostats are obtainable.

As a guide, I show the flow of current by the small arrows on the illustrations, giving a clearer idea of just how the current flows through the different sections of the circuit.

It is well to remember that it does not make a particle of difference on which side of the line the rheostat is connected. The effect is just the same whether rheostats are on the positive or negative sides of a direct current system, and it does not make any difference whether the rheostat is connected in series with the upper or lower carbon of the arc lamp as long as it is in series with the circuit at some point.

It is also well to remember that almost any rheostat offers a lower resistance when it is cold than when it becomes heated, and the increase in resistance of the average rheostat is about 15 to 20 per cent. This means that if you start the arc lamp and measure the amperes, the ampere meter may read 30, but within 5 or 10 minutes' time when the resistance units become heated, the ampere meter would show anywhere from two to five amperes less current flow. The above statement is based on the average commercial rheostat using iron or nickel-steel or german-silver wire. Rheostats can be constructed to give a constant voltage drop, but as a general rule, the resistance increases and consequently the voltage will also increase across the rheostat, and as a result thereof, the current in amperes at the arc will decrease as the temperature of the rheostat increases.

SPECIAL TYPES

Up to this point we have considered only the ordinary means for the control of direct current motion picture arc lamps, and we have found that a resistance unit, usually called a rheostat, can be and is generally used for this purpose. There are, however, other means and methods which can be employed for the control of direct current motion picture projector arcs, some of which are practical, and others impractical, although any of the following systems of control will work.

Suppose we have a 50-volt 25-ampere projector arc lamp to be operated upon a 110-volt direct current constant potential system. We have found that in a case of this kind it is necessary to introduce in series with the arc a resistance unit, or a rheostat, having a potential drop of 60 volts when 25 amperes is flowing through the circuit. It is evident that any other form of resistance offering a drop of 60 volts can be used.

Incandescent Lamp Type.—As an illustration of this, I submit Fig. 94, which shows a bank of incandescent lamps connected to operate in multiple with each other and in series with the arc. In Fig. 94, there is illustrated a properly fused line switch connected to a 110-volt circuit, together with fifty 120-volt one ampere incandescent lamps—in other words, about the same as the regular 32-candlepower incandescent carbon filament lamps. The lamps are connected in multiple and one of the terminals is connected to the line, the other terminal to one of the carbon holders of a projector arc lamp. The other terminal is connected directly to the second carbon holder, making a complete circuit through the arc and through each individual one of the 50 incandescent lamp filaments.

When this system is in operation with the arc at 50 volts, it is evident that the lamps receive only 60 volts. When a 120-volt 1 ampere lamp is operating on only 60 volts, the amperage taken by the lamp is approximately 50 per cent. or ½ ampere, therefore, the arc will be regulated by the incandescent lamps and will receive approximately ½ ampere through each lamp, making a total of 25 amperes at the arc with 50 lamps connected as illustrated.

This method of operation is perfectly safe, providing the main line is wired, fused and switched for 50 amperes, which is the total capacity of the bank of lamps when operating directly on 110-volt circuit, in which case the lamps were installed in the regular way and the arc used course, not be possible unless the carbons are held together, and this would extinguish the arc. The system is exactly the same as if fifty ordinary 32-candlepower lamps were installed in the regular way and the arc used as a switch, or as a dimmer for the incandescent lamps. When the arc is maintained at 50 volts, the incandescent lamps receive only 60 volts, giving a correspondingly lower candlepower, in fact the filament will slightly more than glow.

Attempts have been made, and some patents have been taken out on the combination of arc lamps with incandescent lamps as rheostats, the object being to secure il-

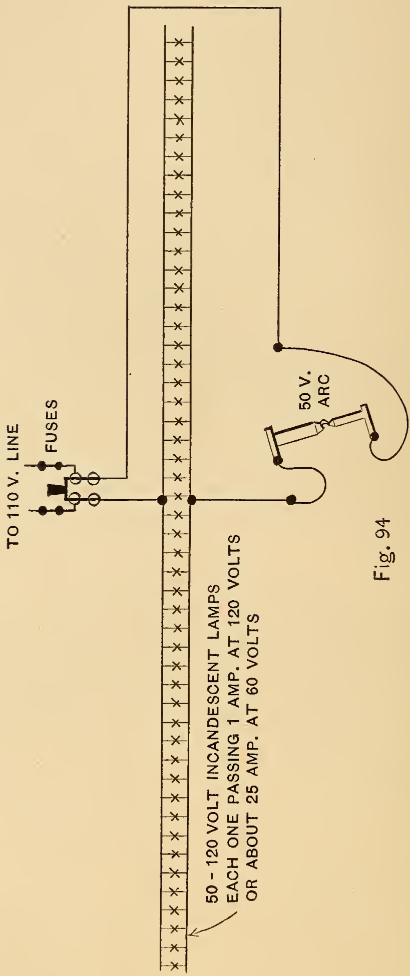

TO 110 V. LINE
FUSES
50 V. ARC
50 - 120 VOLT INCANDESCENT LAMPS
EACH ONE PASSING 1 AMP. AT 120 VOLTS
OR ABOUT 25 AMP. AT 60 VOLTS

Fig. 94

lumination from the incandescent lamps as well as from the arc, thus utilizing some of the usual waste in the rheostat with direct-current systems, but if any great degree of illumination is to be had from the incandescent lamps, they would necessarily have to be made for lower voltage, and the exact correct amount would be 60-volt lamps, each one allowing about one ampere to flow, in which case 25 lamps only would be required. The great danger in this case would be that at the instant the carbons are put together to strike the arc, the 60-volt lamps would for an instant receive 110 volts, or 50 volts more than they are intended for, which would be likely to burn them out.

Considering this scheme of regulating the arc from all points of view, there appears to be no practical advantage in its application, as under the very best conditions the amount of light received from the incandescent lamps would be very small and could only be used in some particular instances for perhaps a novel advertising scheme, but the system is not recommended. At the same time I wanted to call it to your attention as being one of the possible means for regulating an electric arc, and it may have its application in certain specified cases, but should be placed in the list of the impractical controlling devices.

Storage Battery Type.—Another method for reducing the line voltage to that required for a projector arc with direct current is to install a storage battery which may be connected in series, but in opposition to the current flowing through the arc in such a manner that the battery will receive a charge at the rate of 25 amperes with a potential drop of about 60 volts when operated in series with a 50-volt arc on a 110-volt direct current constant potential system.

Fig. 95 illustrates such an installation, and for the purpose there would be required about 25 cells of storage battery, each one of a capacity to stand a continuous charge of 25 amperes. You will note that I have illustrated a small ballast, or steadying resistance, in series with the arc with this system. This is to prevent excessive flow of current through the battery at the time the arc is struck, and also to assist the regulation.

This method of regulation may be of some advantage in cases where the electric energy stored in the battery can be made use of for some other purpose. As an illustration, I may mention that the energy from the storage battery could be made use of for the operation of vacuum cleaning motors, or for slot machines—in fact for any purpose where a low voltage direct current is of advantage. It is understood that this energy received from the

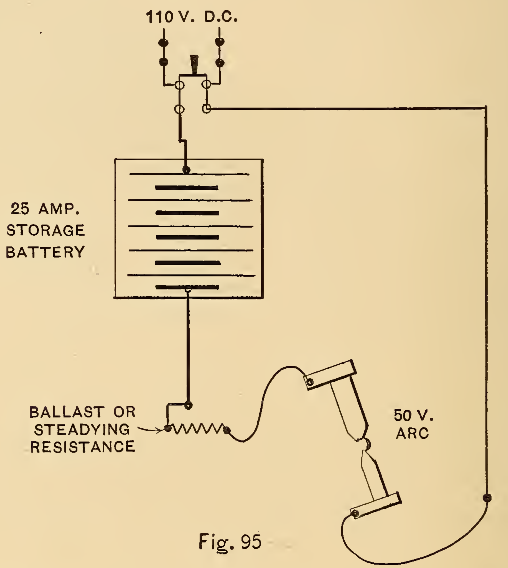


Fig. 95

storage battery is only about 50 or 60 per cent. of the amount put in, but still it is a saving of at least 50 per cent. of the amount generally wasted in the rheostat. It cannot be said that this method of control is practical, although it may have its application in certain places and under conditions suitable to it, and it may be of advantage to some readers to know that it is possible to use it. This system may, however, be placed in the list with other impractical controlling devices for the direct current projector arc.

Water Type.—Where a resistance unit of the ordinary rheostat type is not available, it is possible to manufacture for quick use a resistance unit which is composed of a barrel with a metal plate at the bottom to which is attached by means of a rubber covered cable one terminal of the circuit, and a second metal plate movable up and down, to which is attached another wire to be connected

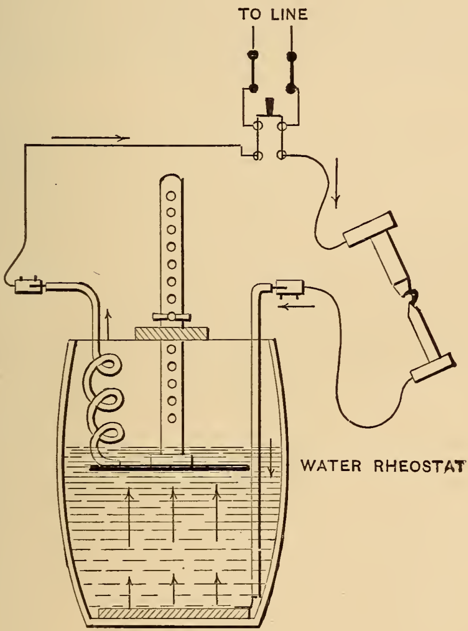


Fig. 96

in series with the arc lamp and the other terminal of the line. When such a device is filled with salt water, it will allow current to pass through the circuit. The strength of current will depend upon the distance between the two metal plates and upon the amount of salt put in the water. Such an outfit is usually called a "water" rheostat and is illustrated in Fig. 96. The lower you set the upper plate, that is, the closer it is to the lower plate, the greater the amount of current that will flow; and the more salt there is in the water, the lower will be the resistance of the water, and consequently more current will flow. Water rheostats are very useful, especially for the higher voltages, in case of an emergency, and operate fairly satisfactorily, although the water becomes heated in a short time and such rheostats require more or less attention.

There are also other methods belonging to the impractical list which I do not deem it necessary to refer to, as they would be of no practical value to the general reader.

CHAPTER IX

D. C. Motor-Generators

AUTOMATIC AND CURRENT-SAVING DEVICES FOR THE CONTROL OF DIRECT CURRENT PROJECTOR ARC LAMPS

IT has been previously stated that the direct current projector arc will operate with best results at a potential drop varying between 50 and 55 volts, and furthermore that it is necessary to connect in series with the line and the arc a ballast, or steadying resistance, across which there must be a potential drop of about 10 to 25 volts for perfect arc regulation.

We have come to the conclusion that a constant potential pressure of 60 volts is the very lowest voltage with which a direct current hand fed projector arc can be properly maintained, and we have also established the fact that it is better to have more than 60 volts; in fact a good average would be 70 volts. Assuming that 70 volts constant potential current is required, it is obvious that in view of the fact that the electric companies supply not less than 110 volts, there is a loss of 40 volts usually wasted in a rheostat in series with the arc and the line. This extra 40 volts is of absolutely no use, but is simply made necessary on account of the excessive line voltage delivered by the electric company. It is not practical for the electric lighting company to reduce the voltage of its system in order to accommodate a few users of motion picture and stereopticon lamps, spot lights, etc., therefore, it becomes necessary for the exhibitor who wishes to economize on his electric current bill and to secure the best results to install a device which will reduce the voltage from 110 to that required by the arc for the direct current projector lamp.

To accomplish this voltage reduction, it is possible to install a motor made to operate on whatever the line voltage may be. This motor should be used for driving an electric generator wound for the proper voltage, which in the case above specified would be about 70 volts. With such motor generator installation changing the line voltage to 70 volts there will, of course, be required a small balast, introducing about 15 to 20 volts potential drop in series with the 70-volt generator and the arc, which is necessary in order to give proper regulation to the arc, as has been described.

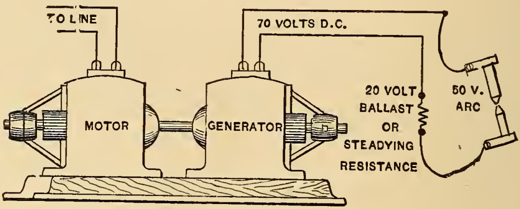


Fig. 97

Fig. 97 illustrates in diagrammatic form a motor generator installation of this kind. On the left is shown the motor, which is an ordinary electric motor of any kind. This may be wound for 110, 220 or 550 volts as the case may require. In the illustration the motor is shown directly connected to an electric generator mounted on the right hand side of the base. This electric generator is somewhat special in that it is made for low voltage, that is, to deliver somewhere between 60 and 70 volts, as the particular requirements of any given installation may demand. The carbons are illustrated with the arc at 50 volts, in series with which there is connected a ballast, or steadying resistance, offering a drop of about 20 volts.

A motor generator set of this kind which is nothing more than an ordinary motor generator outfit, is comparatively inefficient when we consider that not more than 25 to 40 amperes will be required for the arc. As a matter of fact, the losses in the motor and the generator almost equal the loss in an ordinary rheostat which would be used to reduce the voltage. The saving would not perhaps amount to more than 15 or 20 per cent. at the most, and as such machines are very expensive, it is doubtful if they would be practical, excepting on the higher voltages, ranging from 200 to 600.

The author has, however, designed a line of voltage reducers for direct current, which, while in appearance re-

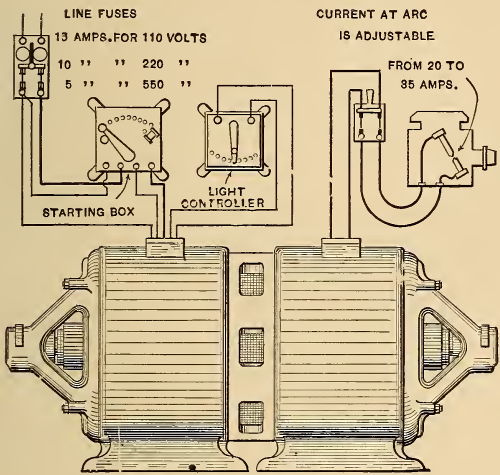


Fig. 98

semble the ordinary motor generator machine, are radically different in both design and construction. Illustration Fig. 98 is a correct representation of such a direct current arc regulator and economizer. The most striking feature of this machine as illustrated in Fig. 98 is that no ballast, or steadying resistance, is required in series with the arc. The machine is absolutely automatic, and the guaranteed saving is 40 to 50 per cent. on 110 volts, 65 to 70 per cent. on 220 volts, and 85 to 90 per cent. on 550 volts.

The machine controls the arc automatically, that is if the carbons are put together forming a short circuit, the amperes on the line will go down, as there is no power used for light. If the carbons are separated a great distance up to the limit of the breaking point of the arc, the amperes on the line also decrease until the arc breaks. The following figures show the input of amperes from the line and the output in amperes at the arc:

Line volts.	Line amperes.	Arc volts.	Arc amperes.
110	15 to 20	50 to 55	25 to 40
220	8 to 12	50 to 55	25 to 40
550	4 to 5	50 to 55	25 to 40

These machines are primarily made for the purpose of saving on the electric bill, but they also possess the advantage of removing the heat from the operating room, doing away with the rheostat entirely, and reducing the size of line wires, fuses, switches and other fittings, which in some instances become quite expensive, especially for amusement resorts, parks, etc., where the wires have to run long distances.

Another important feature is that the machines are furnished with light controllers or regulators, by means of which the candle-power of the projector arc lamp can be increased or decreased at the will of the operator. The controller is also intended to compensate for big drop in voltage on the line as often happens when the load is heavy on the electric company's service.

Where the city authorities limit the amount of amperes which can be taken from a line for picture projection, these machines are very useful, because it is possible to get 40 to 50 amperes at the arc with only 30 ampere line fuses and switches, besides saving a large percentage on the electric bill.

Another point of advantage is that where the electric company supplies current on a 3-wire system, these machines may be connected on the two outside wires operating on 220 volts with only 10 ampere fuses, which, of course, prevents the usual dip in candlepower of incandescent lamps on the same system every time the motion picture lamp is switched on.

CHAPTER X

Alternating Current Projection

DIRECT CURRENT flows in one direction continuously and is therefore sometimes called continuous current, and that on account of the fact that the direct current flows in one direction it is possible to centralize the greater part of the heat at the positive carbon or crater of a direct-current arc. This centralization of the energy at the positive crater is very desirable for projector arc lamps, because it is easy to focus the light from one crater only.

With direct-current arc the light rays from the negative crater are entirely disregarded and it is not necessary or practical to bring the light rays from the negative crater in proper focus to assist in the illumination on the screen.

The temperature at the positive crater of a direct-current arc is more than double the temperature of the negative crater, therefore the positive crater is extremely brilliant as compared with the negative crater. It would be a difficult thing to make use of the illumination from the crater on the negative carbon, on account of the distance between the two carbon points or craters which necessarily has to be maintained in order to secure proper combustion of the carbons.

It is conceded that a good average illumination can be secured from the positive crater of a direct-current 25-ampere arc and for better results the current may be increased to 30 amperes and in special instances, where a brilliant picture is necessary, the current at the arc may be increased from 30 to 50 amperes.

In chapter 2 are described the methods of generating and distributing alternating current.

With alternating current the problem is more difficult because of the fact that the current at the arc is inter-

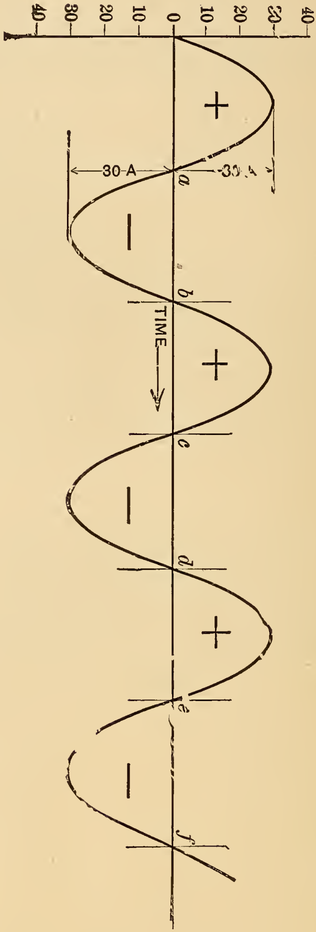


Fig. 99

rupted or, in other words, the arc is dead as many times per second as the current reverses. The number of reversals of the current depends upon the cycles or frequency of the system.

In Fig. 11 you will find a graphical demonstration of an alternating-current system showing three complete cycles, and for convenience I submit the same illustration, Fig. 99.

If you begin at the (o) point, you will note the current travels with the time up to 30 amperes in the positive direction, that means, the upper carbon will be subject to a positive flow of current increasing from (o) to 30 amperes and then falling to nothing at (a), from which point the current continues in the negative direction to 30 amperes, then dropping again to nothing at point (b) and so on. If you stop to think that between (o) and (b) one-sixtieth of a second has elapsed, you will see that the upper carbon has had one positive impulse and one negative impulse, and during the same period the lower carbon has received one negative and one positive impulse, and as it is impossible to reverse the current without putting the arc out, and there being two reversals in one cycle, the arc must have been out twice during one cycle. If we prolong the horizontal line of Fig. 99 to cover a period of one second, we would have just 60 cycles or 60 complete reversals on an ordinary 60-cycle system, which makes it evident that on the 60-cycle system the arc is absolutely out 120 times per second.

You should understand that for projecting work, the craters only are of value as a light-giving medium. The arc proper is of no value, it only serves as a means for carrying the current from one carbon point to the other so as to heat the carbon points to a sufficiently high temperature to volatilize the carbon, thus producing, when combined with the proper amount of air, the great intensity of the electric arc crater which is really the essential element for good projection. Therefore, it is the aim to maintain the brilliancy and constancy of illumination at the carbon points as great as possible. With alternating current this is difficult, because of the interruptions.

When the cycles change, the current momentarily stops, which gives the carbon point a chance to cool off to a small degree, but at the same time to a sufficient extent to make it noticeable as compared with direct current where the temperature is practically constant. As referred to above, the current flows first in one direction, then in the other, which makes the upper carbon positive and the lower negative at one instant and at the next instant the upper carbon is negative and the lower carbon is positive, and so on. The positive crater on d. c. is twice as hot as the negative, which means that it is, of course, much more brilliant. With an alternating-current arc the lower carbon point is just as hot as the upper carbon point, consequently the light-giving quality of the lower carbon crater is of just as great value as the crater on the upper carbon, which, as before stated, is not the case with the direct-current arc.

With the a. c. we have an entirely different condition than with direct current. We must, if it is necessary to secure maximum illumination from the arc, be able to place the carbons in such a relation to each other and to the system of lenses on the projector machine, that not only the upper carbon crater can be focused, but the lower carbon crater as well, otherwise the illumination would be less than one-half as compared with direct current for the same number of amperes at the arc.

The alternating current electric arc maintained between two carbon points produces different results than the direct-current arc, and the main differences may be enumerated as follows:

One: With a given number of amperes and voltage drop across the arc the alternating-current arc between two ordinary carbon points, produces about 50 per cent. less useful illumination for projector work than direct current.

Two: The alternating current projector arc operates with 25 to 30 per cent. lower potential drop as compared with the direct-current arc.

Three: The alternating-current arc is more unstable and difficult to control unless carbons of very small diameter are used which would be impractical with projector lamps.

Four: The alternating-current arc cannot be maintained between one cored and one solid carbon, because the core of each carbon being made from a material which volatilizes with greater ease than the main body of the carbon is necessary in order to sustain an auxiliary, flame or medium by which the arc proper can be re-established after each reversal of the current.

Five: The alternating current arc as controlled by rheostat cannot be maintained in proper form for projection with the frequency below 40 cycles per second. The greater the number of cycles, the better and more constant will be the illumination from the carbon points of an alternating current arc. The tendency, however, on the part of the elecric lighting companies, is to install new generators and transforming devices for distributing not to exceed 60 cycles, and most of the old systems which have been in operation during the past twenty years varying in frequency from 100 to 140 cycles have now been replaced; therefore we are most concerned about the operation of projector arc lamps on the more modern systems which deliver from 25 to 60 cycles.

Six: The alternating current arc produces craters on the extreme ends of the carbons of equal temperature and intensity. In other words, the light-giving power from the crater on the upper carbon is the same as on the lower carbon. There is, of course, a likelihood of the crater on the upper carbon operating at slightly higher temperature on account of the fact that it is generally above the crater on the lower carbon, which would tend to increase its temperature, but for practical projection purposes the temperature and the light-giving power of the upper and lower carbon craters may be considered equal.

CARBON SETTING

Considering what has been said previously, and the foregoing references to the alternating current arc, one can easily understand that it is absolutely necessary to so arrange the carbons, the craters, and the arc, that it is possible to focus the illumination from both craters simultaneously by the means of one set of lenses on one spot.

With the ordinary methods for the setting of the arc lamps and carbons for motion picture projection and where the arc is controlled by an ordinary rheostat, a choke coil, or similar current-saving device, it is neither practical nor possible to focus the illumination from both craters simultaneously.

This point is well worthy of careful consideration, and more thought on the subject will convince the reader that failures in the past when using the alternating arc for motion picture projection are mainly due to the neglect of placing the carbons in proper manner to secure illumination from both craters at the same time.

Some motion picture operators have been satisfied with illumination secured from the crater on the upper carbon, which is the only medium available when the carbons are set as is customary with direct current, at an angle varying from 20 to 25 degrees.

It is a noteworthy fact that only 50 per cent. of the total illumination from both craters is used from an alternating current arc having the carbons set at an angle as is customary for direct current projection.

It does not take an expert to realize that unless both carbon points or craters are put very close to each other and both craters are in exactly the same relation and position to the condensing lenses, it is not possible to secure the total available illumination from an alternating current arc.

Having established the fact that with the direct current arc carbon-setting, only the upper crater can be focused, it is evident without further explanation that it is absolutely necessary to use a different carbon setting than is customary with direct current for alternating current arc projection.

I have given a great deal of thought to this subject, and have carefully studied and experimented with the alternating current arc for motion picture projection, and have come to the conclusion that an entirely different carbon setting and method of control and operation must be employed with the alternating current where high efficiency, perfect illumination and regulation is to be obtained.

The subject of the alternating current projector arc is very simple to those who have mastered the details, and unless the details have been mastered, it is impossible to secure universally satisfactory results with the alternating current arc. This statement is borne out by the fact that

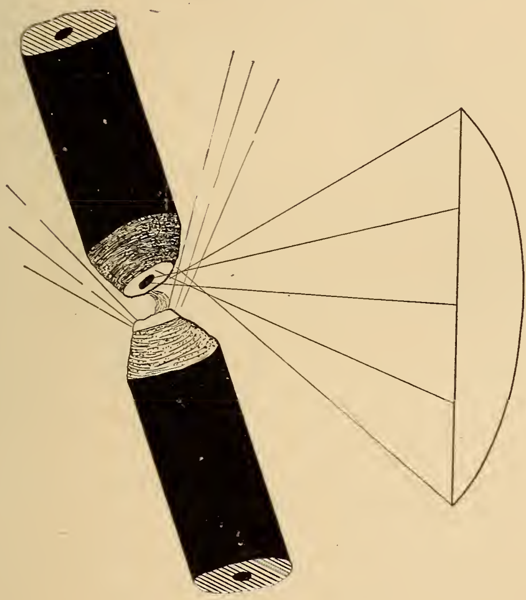


Fig. 100

many operators who understand the details and functions of each element produce splendid results with alternating current, even with inferior current supply, carbons and controlling devices, whereas others produce unsatisfactory results having the best equipment possible at their disposal.

I purpose to make the matter of the alternating current electric arc absolutely clear to all interested in the art, and for that purpose I submit sketch, Fig. 100, which is a representation of two ⅝-inch soft-cored carbons, between which an electric arc is maintained with alternating current. The illustration is intended to represent the condition of the carbon points when the arc is operating at a potential drop of about 40 to 45 volts, controlled by rheostat, choke coil or the ordinary current-saving transformers. If you will analyze Fig. 100, you will find that the crater of the upper carbon only, is within the focus of the lens, due to the following reasons:

First.—The carbons being in practically perfect alignment, are tilted backwards at an angle, exposing the crater of the upper carbon only.

Second.—The arc proper is practically out of focus, excepting the upper part of it, which is in front of the upper crater and the presence of the arc, which cannot be avoided, throws a mist in front of the upper crater, which diminishes the illumination, and at the same time introduces the purple or violet "ghost" so common on the screen when the alternating current arc is used.

Third.—The crater of the lower carbon is entirely useless as an illuminating medium, because it cannot be brought into focus at the same time with the upper crater, on account of the length of the arc necessary when controlled by ordinary means, as above referred to, making the distance between the two carbon points too great for simultaneous focusing.

Note also that the lower carbon crater faces away from the lenses, throwing its light in a direction opposite to that required.

Considering these important points, you will agree and can readily make up your mind to the fact that only the upper carbon crater is of any value when the carbons are set at the angle illustrated, or, in other words, as is customary for direct current projection. The result of this condition is that only 50 per cent. of the total illumination available can be used with such carbon setting.

One might ask the question: "Why not put the carbons in some other position so that both craters can be focused simultaneously?" This can be done to a limited extent with ordinary methods of arc control, as previously referred to, but can never be done when the direct current setting is employed.

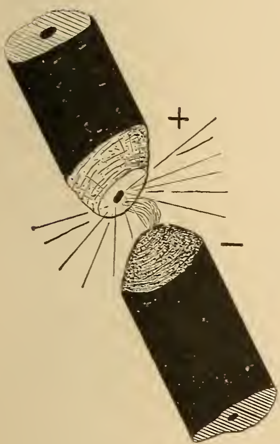


Fig. 101

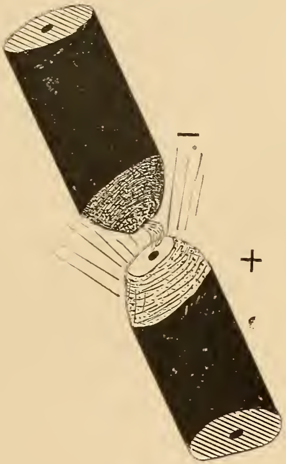


Fig. 102

For further consideration, and to make the matter still more clear, I submit Fig. 101, which shows the alternating current arc at the instant the upper carbon receives the positive impulse. At that instant, the upper carbon crater is at maximum intensity, and the lower carbon crater is of much lower intensity. In fact, Fig. 101 can be compared with the ordinary direct current arc where the upper carbon is connected to the positive wire, but only for one instant, or for 1/60 of a second on a 60-cycle system.

Fig. 102 is intended to show the alternating current arc at the instant when the lower carbon receives a positive impulse, under which condition the lower crater is at maximum intensity, causing the upper crater to give a very small amount of illumination, as would be the case with a direct current arc if the wires were reversed so that the lower carbon would be connected to the positive wire, which, as is generally known, would give a purple and unsatisfactory illumination.

A careful consideration of Figs. 101 and 102, therefore, sets forth additional facts of great importance, because they illustrate how the alternating current are when used with the direct current carbon setting at an angle, not only has to work at the disadvantage of having only the upper crater subject to focusing, but at the same time, whenever the frequency changes, or, in other words, when the current reverses, the upper carbon crater loses more than 50 per cent. of its intensity, as compared with direct current.

There is another important point which must be remembered, and that is when the upper carbon on an alternating current system receives a positive impulse, it does not receive a full flow of current at once, or for the total period of the cycle, because the alternating current, when it flows in the positive direction, begins at zero and rises up to the maximum current flow, and then drops again to zero, which means that there is only a very short instant during which the full amount of current flows.

When you compare these conditions with the direct current arc, the alternating current system is at a great disadvantage under ordinary conditions and with ordinary control, because with direct current, which flows continuously in one direction, the positive crater maintains continuously maximum temperature and therefore highest illuminating intensity.

Most operators are aware of these facts and overcome some of the disadvantages by different carbon settings, some of which improve the results, but the fact still remains that the alternating current projector arc operates at the greatest disadvantage when the carbons are set as illustrated in Fig. 100, or, in other words, when the regular direct current carbon setting is used with alternating current.

There are many ways for setting the carbons, and as we are considering the more important methods or ways of setting the carbons for alternating current, a modified form of carbon setting for alternating current in which the lower carbon is placed perpendicular and the upper carbon is placed at an angle relative to the lower carbon, as illustrated in Figs. 103 and 104.

With the ordinary means of control for the alternating current arc, including the rheostat, choke coils and the general run of current-saving transformers, there is no particular advantage in placing the carbons as illustrated in Fig. 103, because even though the lower carbon be set straight up and down, its crater cannot be focused simultaneously with the crater of the upper carbon, due to the fact that the distance beween the two carbon craters is too great, and besides, the lower carbon faces directly upwards, so that at the very most only the front upper edge of the lower crate would be useful as an illuminating medium, and, as already stated, it is too far below the upper crater to make it of any value as an illuminating medium.

The only possible advantage with this carbon setting when the arc is controlled by ordinary means of current control, as above mentioned, lies in the fact that the lower carbon is swung out of the way, as you might say, of the upper crater, interfering less with the rays of light from the upper carbon crater. If you will look again at Fig. 101, you will find that the point of the lower carbon is slightly in front of the lower edge of the upper carbon crater, cutting off some of the illumination. This trouble is done away with when setting the carbons as illustrated in Fig. 103.

The carbon setting shown in Fig. 103 is extremely difficult to handle, because as the upper carbon burns away, its crater gradually gets back further and further from the center of the lower carbon point, thus making it necessary to push the upper carbon forward or readjust the upper carbon clamp so that the upper carbon will be put at a greater angle, in that way pushing its crater forward, or by swinging the lower carbon point backward so as to maintain the same relative position, as illustrated in Fig. 103, between the two carbon points. Expert operators can do these stunts, but it is a difficult job and requires a

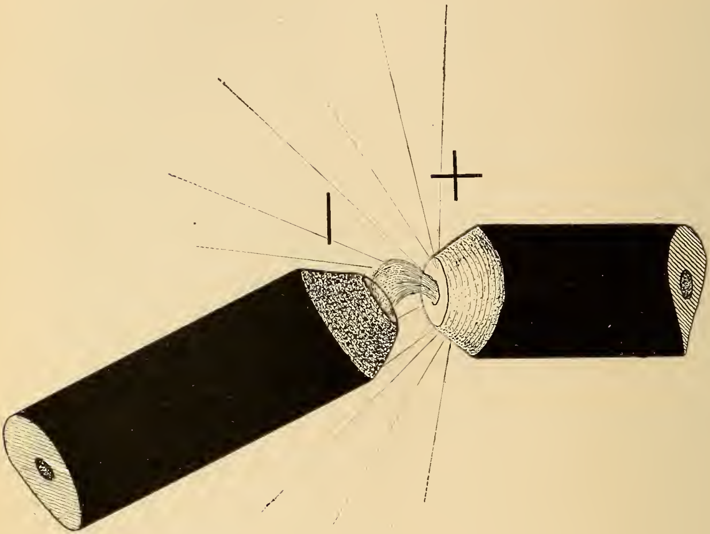


Fig. 104

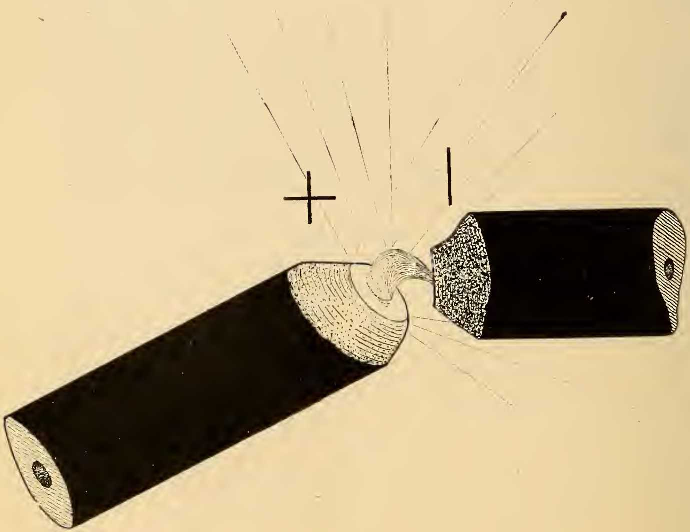


Fig. 103

great deal of judgment and care so as not to interfere with the continuous operation of the light while the picture is being exhibited.

The gain by putting the carbons as illustrated in Fig. 103 when the alternating current arc is controlled by the ordinary means, as already referred to, as compared with the carbon setting shown in Fig. 101 is not sufficiently great to warrant introducing the possible chance of trouble by setting the carbons as shown in Fig. 103. Therefore, the carbon setting as shown in Fig. 103 is not recommended for general use with alternating current, excepting in cases where special means of current control are introduced. This setting is of value, however, where the motion picture lamp is provided with the backward and forward adjustment for the upper carbon, controlled outside the lamp-house, as is now general in the more modern motion picture lamp equipment.

To further explain the exact distribution of illumination from the craters with the carbon setting as illustrated in Fig. 103, I have introduced Fig. 104 for comparison.

Fig. 103 illustrates the arc and light distribution when the upper carbon receives a positive impulse, at which instant the upper crater gives maximum illumination, and the lower crater a comparatively small amount of illumination. Fig. 104 illustrates the reverse condition, that is, when the lower carbon receives a positive impulse, at which instant the lower crater gives the greatest amount of light and the upper crater a comparatively low amount of illumination.

Summing up what has been said about this form of carbon setting, it will be easily understood by any careful observer that the upper carbon crater is really the only important light-giving medium, although the upper front edge of the lower crater also contributes some illumination, but a comparatively small amount.

The foregoing arguments set forth together with illustrations and the descriptions, should clearly demonstrate the fact that

> with alternating current at the arc of a projector lamp, only one of the craters produces light of any magnitude at a time.
> The fact has also been brought out that on account of the distance between the carbon points necessary in order to maintain a proper arc with the ordinary means of current control for such arcs prevents the focusing of upper and lower craters in one spot with the same system of lenses.

Another matter of importance which has been brought to your attention is that

> the point or crater of the lower carbon, if said carbon sits straight up and down or is tilted backwards, cannot be of any material benefit as an illuminating medium in a projector arc, because the upper surface of the lower carbon being flat or even tilted backwards does not distribute any great quantity of illumination towards the condensing lenses, even though it should be possible to focus the upper and lower craters simultaneously, which is not practical with ordinary means of arc control, such as rheostats, choke coils and ordinary current-saving transformers.

Those who have made a study of the alternating current electric arc and who have had a great deal of experience know that the foregoing statements are absolutely correct and are borne out by practical experience.

It would seem reasonable, in view of past experience, to suggest that it is possible to make use of the illumination from both the upper and lower crater with an alternating current arc by putting the carbons at an angle relative to each other and to the condensing lenses, which will permit the total illumination from both craters to come within the reach of the condensing lenses. Such a carbon setting has been tried by many operators, and under certain conditions this carbon setting is very satisfactory. Fig. 105 shows the light distribution from such a carbon setting when the upper carbon receives a positive impulse. Under these conditions, the upper carbon crater is at maximum intensity and within the focus of the lenses.

Fig. 106 is intended to illustrate the light distribution with this same carbon setting at the instant when the lower carbon receives a positive impulse, under which condition the lower crater will reduce maximum illumination and at that same instant the upper carbon crater produces a comparatively small amount of illumination.

I have tried to make Figs. 105 and 106 as true to practice as possible, and you will agree that the separation between the two carbon points is about as small as can conveniently be maintained with a proper arc with the ordinary means of current control. A study of the accompanying illustrations should convince you that, notwithstanding the fact that both craters are put in a position where they practically face the condensing lenses, it is not possible to bring both craters in focus on one spot, on account of the distance between them. The carbon setting illustrated in Figs. 105-106 may give more total illumination in the direction of the condensing lenses, but the net result is practically no better than from carbon settings illustrated in Figs. 100 and 103.

This statement may seem unreasonable to many, but when the reader takes into account the point that the condensing lenses of a projector arc lamp bring into focus on the spot at the aperture plate an exact image of the craters, it is easy to understand that there will be a very brilliant spot on the upper part of the aperture from the lower crater and another brilliant spot on the lower part of the aperture from the upper crater, but right in the center there will be a purple or violet streak which represents the arc which is not backed up by a crater, but which is in front of the air space between the rear part of the upper and lower craters.

Having mastered the foregoing argument, you will readily understand that in order to focus both craters in Figs. 105 and 106 it would be necessary to bring the rear

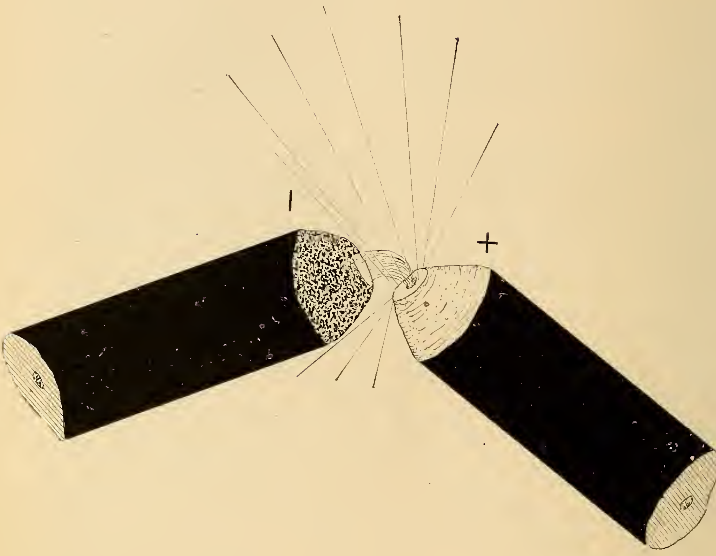


Fig. 106

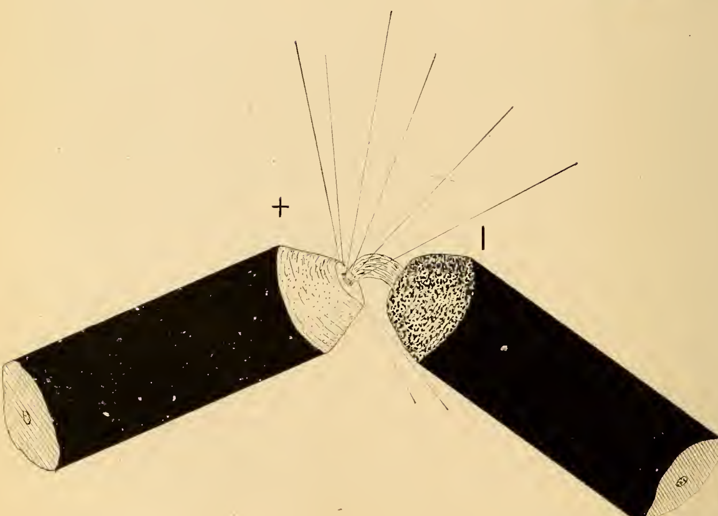


Fig. 105

end of the carbon points together, so that they not only touch but overlap each other, and this is impossible to do and still maintain a proper arc with proper consumption of the carbons and proper maintenance of the shape of the craters using a rheostat, choke coil or ordinary current-saving transformer.

Operators of experience know that if, under the conditions specified, the carbon points are put close to each other in the rear, that is, so close that the craters touch each other. In other words, if you allow the carbon points to freeze, the arc will be diminished, operating at a much lower voltage drop than normally, thereby, of course, reducing the number of watts at the arc. This in turn cuts down the candlepower of the craters. so that while the craters may be in that condition focused simultaneously, the candlepower is so much lower that there is no benefit in operating under that condition. It would be far better to operate with only one of the craters, as illustrated in Figs. 100 and 103.

The carbon setting illustrated in Figs. 105 and 106 also tends to make the arc unstable, because of the very great distance between the front part of the craters as compared with the rear, making the illumination rather unsteady, as compared with carbon setting illustrated in Fig. 100.

In view of the foregoing, there is no particular advantage in setting the carbons as illustrated in Figs. 105 and 106, with ordinary means of current control. The setting is more complicated than the ordinary setting in Fig. 100 and does not produce better results. There are, however, conditions under which it is of advantage to set the carbons as illustrated in Figs. 103 and 105, but now when the arc is controlled by a rheostat, choke coil or ordinary current saving transformer.

CHAPTER XI

A. C. Economizer

OF the various carbon settings referred to, it might be stated that the setting illustrated in Fig. 100 will give universal satisfaction when the arc is controlled by any of the means or devices specified in the preceding chapter.

It is equally true that skilled operators can produce good results with these devices with a carbon setting as illustrated in Fig. 103, although it is more difficult to manipulate the carbons and to always keep them in proper relation to each other.

It may also be taken as a fact that a carbon setting similar to Fig. 105 will give satisfactory results with any of the current controlling devices mentioned. It is, however, generally recognized that the advantages of setting the carbons as illustrated in Figs. 103 and 105 are not sufficiently great to warrant the use of this setting as compared with the more all around satisfactory and more easily manipulated carbon setting as illustrated in Fig. 100, which may be considered the standard when the arc is controlled by ordinary means on alternating current.

The writer, having been in constant daily touch with the development of arc lamps arc lighting apparatus, arc lamp controllers and similar devices for many years past, has made an exceptionally careful study and has had unusual opportunities to investigate and test the electric arc under different conditions and for different purposes.

Some seven years ago, I made most exhaustive tests and experiments with the alternating current electric arc for motion picture projection and established the fact that it is absolutely necessary, in order to secure perfect results with a. c. at the arc, to so arrange the carbons that both the upper and lower craters can be focused with the same system of lenses and at the same time in one single spot.

These tests further demonstrated the fact that it is impossible to put and maintain the carbon points close enough together to permit the focusing of both carbon craters at the same time and to eliminate the purple arc, with rheostat, choke coil or ordinary current saving transformer control.

As a result of the foregoing, a line of specially designed semi-constant current transformers were developed by the writer for the purpose of delivering to a projector arc lamp a modified current which will permit the focusing of both carbon craters at the same time and which will eliminate the purple arc. These semi-constant current transformers are well known to the trade under the name of the Hallberg Automatic Electric Economizer.

This device operates on the principle of the constant current transformer described in Chapter III, illustrated by Figs. 20 and 21. It is practically constructed along the lines of Fig. 21, but is provided with two or three extra *taps* in the primary winding. These taps are arranged to include all nine turns of the primary winding for highest line voltage and a lesser number of turns for medium or very low line voltage. For further information regarding the operation and connection of this device, study the chapter on the Hallberg A. C. Economizer, together with references to it under heading "Questions and Answers for Operators."

In order to make the value and advantages of this arc controlling device perfectly clear to the reader, and also in order to demonstrate the relative advantages and disadvantages of setting the carbons at the usual angle as illustrated in Fig. 100, as compared with the perfectly vertical carbon setting recommended to the users of the economizer, I present photographic reproductions of the arc phenomena and light distribution, which have been prepared at a considerable expense.

The reader who has made a study of the alternating current electric arc will at once appreciate the extraordinary results which can be obtained by the vertical car-

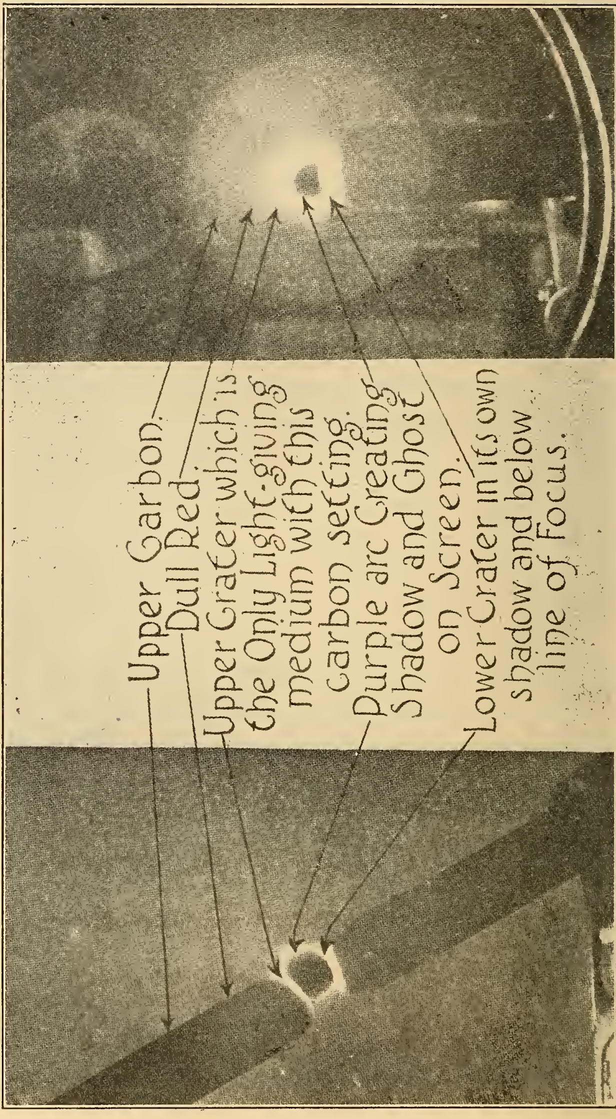


Fig. 107

Fig. 108

bon setting when the arc is properly controlled. I do not want the reader to get the impression, however, that the vertical carbon setting can be used with all kinds of current controllers, because it cannot. The vertical carbon setting was devised and recommended for use with the economizer only, and when used in combination with this device, under proper voltage and cycles, the best results that can possibly be obtained with a. c. at the arc will be realized. In fact it is possible with this equipment to equal a d. c. arc projection with the same number of watts taken from the line up to 30 ampere d. c. arc.

Fig. 107 is an exact reproduction of a 45-ampere alternating-current arc maintained between two carbons set at the angle universally adopted for direct and alternating current projection with ordinary means of current control.

Fig. 108 is an exact representation of the same electric arc looking into the front of the lamp house with the condensing lenses removed.

These illustrations are instructive and interesting, and I call your particular attention to the upper crater, which it will be seen is the only light-giving medium that produces white illumination in proper focus. The purple arc is somewhat below and in front of the white upper crater, and instead of distributing illumination on the screen it does great harm, in that it casts a purple shadow (usually called the "ghost" on the screen). Note that the purple arc in Fig. 108 cuts off almost fifty per cent. of the upper crater, reducing the candlepower. The crater of the lower carbon can barely be seen, as it is in its own shadow, and besides it is below the line of focus and is, therefore, of no particular illuminating value.

Notwithstanding the fact that the arc is extremely inefficient when the carbons are set as illustrated in Figs. 107 and 108, many operators continue to use this carbon setting, because their current controllers do not permit the setting of the carbons to advantage in any other way.

Fig. 109 is an exact reproduction of the a. c. arc in an ordinary moving picture machine lamp house operating on 60-cycle alternating current between two high grade ⅝ in. soft cored carbons. The photograph from which this cut was made was taken after the arc had been in operation about three-quarters of an hour, so as to secure a reproduction of the carbon points and the arc when in normal use.

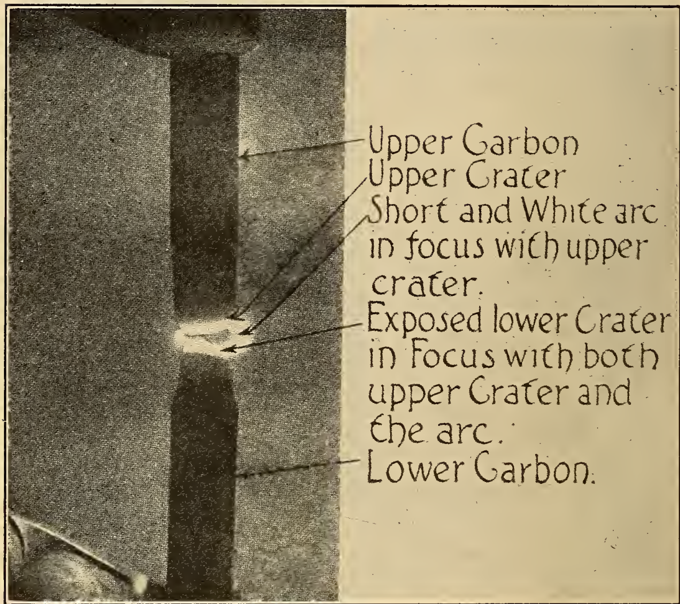


Fig. 109

I desire to call particular attention to the surfaces of the upper and lower craters, both of which are fully exposed, slanting at a slight angle, opening in wedge form toward the condensing lenses, touching each other in the rear so as to form two perfectly white surfaces joining each other at the extreme rear point. This form of crater permits the focusing of the upper and lower craters at the same time with the same system of lenses in a single spot, producing practically double the amount of illumination as compared with the carbon setting illustrated in Fig. 100 and Figs. 107 and 108.

Attention is also directed to the arc in Fig. 109. The arc is very short and is absolutely white, so that instead of being a detriment like the long purple arc referred to above, the arc actually increases the amount of white illumination and makes the crater surfaces blend together in a pure white light without shadows on the screen.

In order to illustrate an absolutely perfect electric arc with proper carbon craters on alternating current, I show Fig. 110, which is the ideal carbon setting for alternating current when the arc is controlled by the economizer, or any other device having similar characteristics.

Whereas, the ordinary a. c. electric arc operates at a voltage of anywhere from 40 to 50, the a. c. arc when controlled by the economizer, as illustrated in Fig. 110, requires only 30 to 35 volts at the arc, which, of course, also means that fewer watts are required and consequently the saving of current is greater.

Fig. 111 illustrates the Hallberg Economizer which controlled the arc at the time photographs for Figs. 109 and 110 were taken, and just as a matter of instruction and advice to operators who are using this device, I want to say that it is of the utmost importance that the carbons be clamped tightly in the holders; that the asbestos covered cables be perfectly attached to substantial lugs; that the lugs be securely fastened to the carbon clamps; that all connections be made and maintained perfectly clean and tight to secure good contact; that the economizer should be placed at least one foot away from the sheet iron lined wall, and last, but not least, that the line voltage does not fall below the amount specified on the name plate of the economizer and, of course, that the cycles are in accordance with the number stamped on the name plate.

Fig. 110

When the above points are properly attended to, then the vertical carbon setting as illustrated in Fig. 110 will produce unequaled results, practically as good as can be had with direct current for the same number of watts taken from the line.

In closing this chapter on the alternating current elec-

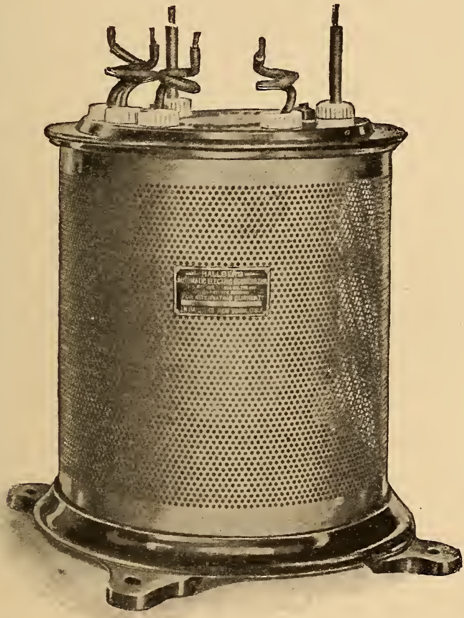


Fig. 111

tric arc, I want to say that the carbon settings illustrated in Figs. 103 and 105 may also be used when the arc is controlled by the Hallberg Economizer, although there is no particular advantage in setting the carbons that way, besides it requires a more expert operator to handle the carbons with those settings.

Practical and Commercial Section

CHAPTER XII

The Hallberg Economizer

ALTERNATING CURRENT AUTOMATIC ELECTRIC TYPE

Special Information and Instructions

WHEN projector arc lamps are operated on alternating current it is necessary in order to reduce the line voltage usually supplied by the electric company from 110 to about 33 volts, which is the usual potential drop maintained across the arc. In the early days, a rheostat was used for this purpose which, instead of transforming the voltage, simply dissipated the difference in voltage at the arc and the line in the shape of heat, at a tremendous loss of energy.

If we consider an arc of 50 amperes at 33 volts, we require an energy of about 1,650 watts at the arc. If we consider the line voltage as being 110 and the amperes 50, the input from the line approximates 5,500 watts, giving a loss of 3,850 watts in the rheostat. At a charge of 10 cents per kilowatt hour, the loss in the rheostat is 38½ cents per hour.

In order to reduce this great loss of current in the rheostat, many schemes have been proposed and used, and among them may be mentioned the commonly known choke coil, also known under the name of reactive coils, impedence coils or inductive coils. These coils generally consist of one or two cores of iron around which a number of turns of large insulated copper wire is wound. The effect of one of these coils upon the line is the same as the rheostat, but due to the fact that the current in a choke coil lags behind the line voltage or electro motive force, the magnetism created in the iron core sets up a counter current which opposes the line voltage, thereby not only reducing the voltage, but at the same time effecting a saving in the watts consumed. When a coil of this description is used, it is connected in series with the arc, exactly as would be an ordinary rheostat, and if 50 amperes are required at the arc, there will be taken from the line 50 amperes, consequently the line wires, fuses, switches, and wiring inside the building must be of a capacity of 50 amperes, or the same as for the rheostat. There is a certain loss in the choke coil which, while being much smaller than in the rheostat, is still considerable. Another matter of importance is that whenever the rheostat, or any form of choke coil, is used, there is considerable flaming at the arc and it is difficult to centralize the illuminating power in a sufficiently small spot on the carbons to permit of proper focusing. This fact accounts for the presence of an uneven field of light on the screen on which there is present what is commonly termed a "ghost," consisting of a shadow in the center or at one side which may be either all black, or more often of purple color, seriously interfering with the brilliancy of the picture.

The Hallberg A. C. Economizer is a specially designed transformer of the semi-constant current type, which means that it will take the line current at a fixed potential and will deliver on the secondary side a practically steady ampere flow, irrespective of the length of the arc. This economizer consists of a continuous rectangular core. On one core leg there is put a primary winding. On the opposite core leg there is placed another coil or winding of larger cross section wire, to which the arc lamp is connected. The primary coil has one beginning end brought in through terminal No. 1. The end of the primary coil is, however, broken into in three separate places by terminal No. 2, which includes a certain number of turns and which is the one to be used when the line voltage is low. Terminal No. 3 includes a few more turns and is used when the line voltage is normal. Terminal No. 4 includes still a few more turns and represents the end of the primary coil, which is used when the line voltage is high.

Fig. 111 illustrates the external appearance of the economizer as connected to the line and to the lamp of a projection machine. The machine switch is always connected on the line side of the economizer. The asbestos covered cables from the lamp are connected directly to the lamp leads extending from the economizer.

This type is regularly furnished for voltages ranging from 100 to 120 or from 200 to 220, and may be constructed for 25, 33, 40, 50, 60 and 120 to 140 cycles.

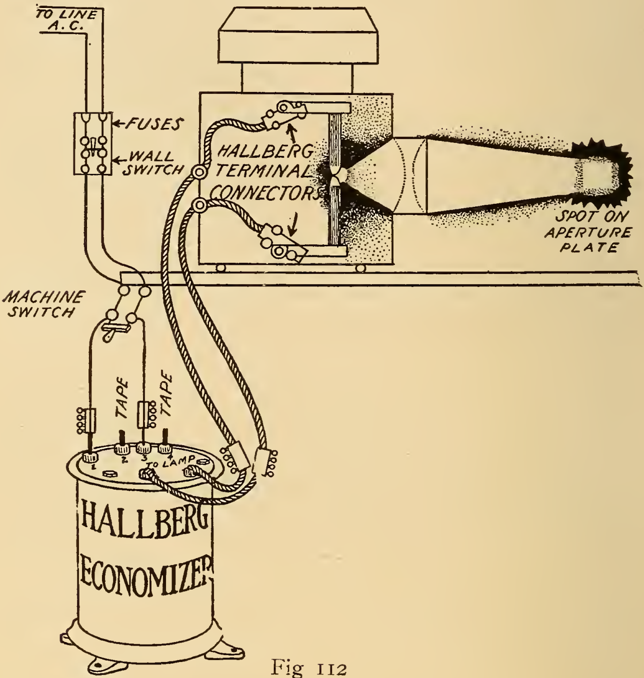


Fig 112

On 110 volts, the economizer line wires are usually attached to terminals 1 and 2 for any voltage from 100 to 105. On 1 and 3 for 110 volts, or to terminals 1 and 4 if the line voltage should vary between 115 and 210. If the economizer is made for 220 volts, then the line wires are connected to 1 and 2 for 200 volts; on 1 and 3 for 210 volts, or to 1 and 4 for 220 volts (see diagram Fig. 112).

Some operators desire varying candlepower at the arc to accommodate lighter, or more dense films. In a case of this kind, it is possible to simply install a 3-pole main line cut-out (with one single fuse plug) connected to the economizer, as illustrated in Fig. 113. By simply putting

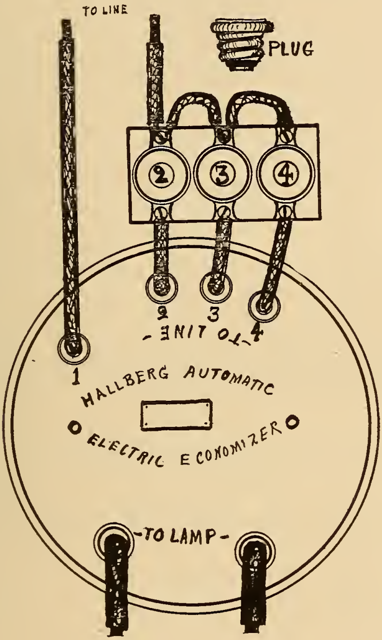


Fig. 113

the plug in terminal No. 2, a heavy amperage is secured. Unscrew the plug and put it in No. 3 and a medium current is secured, and for still less light, unscrew the plug and put it in terminal No. 4. This arrangement is exceedingly simple, cheap and practical and will never wear out or give trouble, and the plug can be instantly changed from one terminal to the other, giving three degrees of amperes at the arc. If more than one plug should be in the cut-out at one time the fuse will blow, because this short circuits few of the primary turns on the economizer. Never use but *one plug* in the cut-out.

"HALLBERG" ALTERNATING CURRENT ECONOMIZER DATA

Lines Fuses Required	Line Voltage	Line Amperes	Line Watts	Amperes at Arc
	Regular Type — 30-40 *Amperes*			
20	110	18	1,400	30-40
10	220	9	1,400	30-40
	Standard Type — 45-55 *Amperes*			
30	110	25	1,800	45-55
15	220	13	1,800	45-55
	Special Type — 60-80 *Amperes*			
40	110	35	2,200	60-80
20	220	18	2,200	60-80
	Search-Light Type — 125-150 *Amperes*			
80	110	75	4,200	125-150
40	220	35	4,200	125-150

The various Hallberg economizers, in accordance with the foregoing data, are intended for certain purposes, as follows:

The Regular type for stereopticon work and very light motion picture theater work where the throw is short and the size of the picture is small and where the performance does not run very long at a time.

The Standard type is the one recommended for every day motion picture performances. It delivers a powerful illumination at the arc and is good for all distances up to about 100 feet, and for pictures measuring as much as 18 feet wide.

The Special type is made for those who desire a more than ordinary powerful light with a. c. at the arc. It has been used with success for distances up to 130 feet, and for pictures measuring as much as 26 feet across.

The Searchlight type economizer was originally designed for Kinemacolor work, but it proved of such great value as a light producer that it is now offered to the regular motion picture trade as a means of producing the most perfect light which can be had with alternating current at the arc. It makes a brilliant white field and when used with ¾ inch or possibly 1 inch diameter carbons, it is entirely practical, especially when the modern large lamp houses are employed, such as furnished by the manufacturers of all latest model machines.

The practical operating success of the economizer depends upon a very few elements:

1. The voltage and cycles of the current must be proper for the economizer.

2. All connections, especially those between the economizer and the carbon jaws, and also between the carbons and carbon jaws, must be clean and perfect.

3. The asbestos covered cables must never be of smaller capacity than No. 6, and for the Special and Searchlight economizers, these cables should be No. 4 and No. 2 respectively.

4. The proper make, style and size of carbon should be used as specified by the manufacturer for each type of economizers.

5. The setting of the carbons should always, wherever possible, be in accordance with instructions furnished by the manufacturer.

SPECIAL DIRECTIONS

For the Hallberg Automatic Electric Economizer for Alternating Current—Standard Type

1. Place economizer at least 12 inches away from sheet iron wall, as otherwise there will be a humming noise.

2. 30-ampere line fuse is large enough for 110, and 15-ampere line fuse for 220-volt circuit for standard type.

3. Connect fuses, switches and wires exactly as illustrated in Fig. 112.

4. Make sure all connections are tight and secure, especially at the carbon clamps in the lamp house.

5. Cover all line terminals on economizer with tape.

6. Use only ⅝ inch soft-cored carbons.

7. Keep arc short, not over 1/32 inch long.

8. Feed carbons often and very little at a time.

9. It is better to use short carbons than to use long

ones, because the arc is better controlled, and the craters will open up toward the condensing lens, giving full illumination on the spot on the aperture plate.

10. The carbon points and spot on the plate should look, as shown in Fig. 112, for best results.

11. If, for some reason, the carbon points do not burn clean, as is the case if inferior carbons are used, or more often, if the line voltage is too low, temporarily improve the light by using a coarse file on the front edge of the upper and lower crater, which will remove the ragged carbon points and expose the craters to the condensers or put plug in No. 2 (see Fig. 113).

12. Low-line voltage, which sometimes happens during the early part of an evening when the electric company's system is loaded heavily; inferior carbons, and loose connections are the three main sources of trouble.

Operators, look out for these points and guide yourselves accordingly.

HALLBERG A. C. TO D. C. ECONOMIZERS

Special Information and Instructions

Those who are familiar with projector arc lamps of all kinds understand that, as a general rule, better illumination and more quiet operation can be obtained by the use of direct current applied to the arc. Alternating current, even under the very best conditions, makes a noisy arc, and due to the fact that the heat is distributed equally on the upper and lower carbon points, it makes it difficult to concentrate the illumination from the upper and lower crater into one single spot on the aperture plate. This is impossible with rheostats and most forms of choke coils and transformers, as with these only a crater from the upper carbon is available as an illuminating medium, thus reducing the illumination with alternating current on the screen about 50% as compared with the same amount of power applied to the arc with direct current.

The tendency of the electric light companies throughout the country is now to install alternating current generating plants and distributing systems, therefore the motion picture exhibitor will in a short time receive only alternating current from the mains of the electric lighting companies. Those who have previously used direct current at the arc will find this change to their detriment, not only on account of the noise at the arc, but also on account of the decreased illumination and in some instances the uneven field and resultant ghost on the screen.

To make it possible for the exhibitors, who are so inclined to secure direct current at the arc from an alternating current supply, the Hallberg A. C. to D. C. Economizer has been developed. It is composed of an a. c. motor which may be made for any voltage from 100 to 600 volts, and for any frequency from 25 to 60 cycles, and it is made for either single phase, two-phase or three-phase current supply.

Fig. 114 shows the external appearance of the Hallberg A. C. to D. C. Economizer. On a common sub-base there is mounted the a. c. motor, which is directly connected to a specially wound generator. The connection is made by a pulley shaped insulated coupling which entirely separates the a. c. from the d. c. system, and this coupling can also serve as a pulley where the d. c. machine has to be used as a generator driven by any other motor, or by an engine of any kind. This is an important point in all Hallberg A. C. to D. C. Economizers and is considered to be of advantage to the exhibitor, as it really gives him the opportunity of putting in a small engine, by means of which the generator can be driven in an emergency, if the electric power should fail, or if the outfit should be installed at a point where the proper kind of alternating current is not available.

The construction of the generator is along the most modern lines, and the arrangement of the brushes and connections is similar to the Hallberg D. C. Economizer, and the same general instructions hold good for the d. c. end of the a. c. to d. c. outfit. The d. c. end of this machine is so designed that a short circuit may be put on

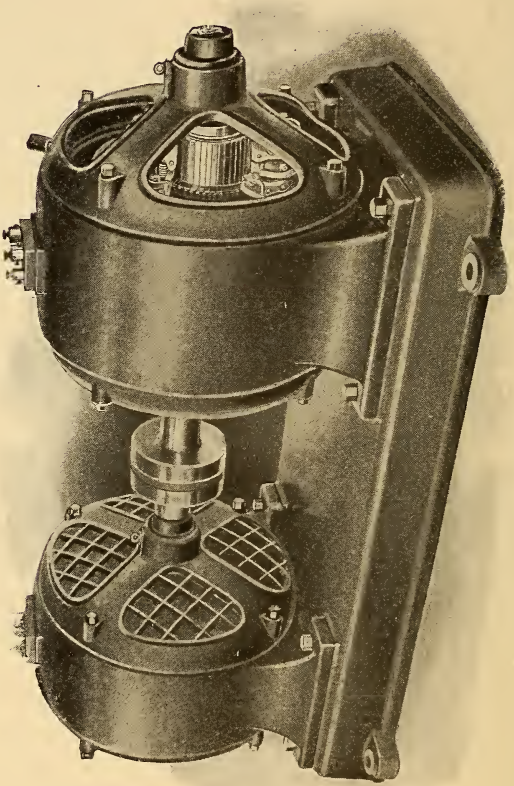


Fig. 114

it without injury to the generator—in fact, the current will drop down to zero if the carbons are put together and held that way for a few moments. This is a point of advantage because it protects the machine from short circuits or overload, and also permits the operation of the motion picture arc without a large rheostat in series with the arc.

Wherever possible, it is desirable to operate the Hallberg A. C. to D. C. Economizer on either two or three-phase circuits rather than single phase, and although made for either 110 or 220 volts the latter is preferable. The economizer is also made for single phase 110 or 220 volts, but the investment is greater for the single phase current than for two or three-phase systems. Hallberg A. C. to D. C. Economizers are made in several sizes. In view of the fact that these machines are installed by exhibitors who appreciate the value of a picture which stands out in great relief where the delicate shadows in the half-tones and high lights are brought out to the greatest intensity, making the actors and scenery stand out life-like, which requires a powerful steady electric arc in the lamp house, these machines are not made up in the smaller sizes for general use. The following sizes are standardized:

FOR ALTERNATING TO DIRECT CURRENT

TYPE	LINE VOLTAGE	PHASE OF CURRENT	CYCLES OF CURRENT	DIRECT CURRENT DELIVERY
A	110 or 220 v. as specified	2 phase or 3 phase	60	25 to 60 amperes with capacity for 70 amp. for short time for 1 lamp, or 20 to 30 amp. for each of 2 lamps
B	110 or 220 v. Interchangeable	Single phase	60	Same as above
C	110 or 220 v. as specified	2 phase or 3 phase	25	25 to 50 amperes for one lamp, or 20 to 25 amp. for each of 2 lamps
D	110 or 220 v. Interchangeable	Single phase	25	Same as above

E	110 or 220 v. as 2 phase or specified 3 phase	60	Up to 100 amperes for one, two, three or four lamps
F	110 or 220 v. Single Interchangeable phase	60	Same as above

These outfits are complete, mounted on cast iron subbase directly connected with light controller to increase or decrease the direct-current output, with complete diagram of connections and operating instructions, giving size of carbons required, etc. As a general rule, the electric lighting companies permit these outfits to be operated without starting boxes, but in some localities, especially where the plant is overloaded, a starting box for the motor end of the economizer may be insisted upon. This can, of course, be furnished whenever specified. These outfits can be made up for any other voltage or cycles, but those given herewith are the most common.

The Hallberg A. C. to D. C. Economizer may be used for the operation of two motion picture arcs at the same time, as is required when it is desired to dissolve the end of one reel into the beginning of the other. This arrangement gives a continuous performance on the screen and can be accomplished by a special form of wiring and the installation of a double lamp control with regulating ballast divided in two units, one for each lamp. This double lamp control arrangement can be installed at any time.

"HALLBERG" A. C. TO D. C. ECONOMIZER

Instructions for Operating

1. Make sure that the machine stands on a bench or table elevated about 30 inches from the floor, so that the machine can be kept clean without the operator getting down on his knees.

2. Put a good grade of dynamo or a medium automobile oil in the oil wells and make sure that when the machine turns, the oil rings which you can see by lifting the cover on each oil well, rotate around the shaft, picking the oil from the well and properly distribute it on both sides. If the machine leans toward one end, the oil will run that

way and the other half of the bearing will not be lubricated. Drain the oil out of the well about once a month through the plug in the bottom and put in fresh oil.

3. Be sure that the small springs on the brush holders are adjusted in the first, or weakest notch on the finger which presses the carbon brush against the commutator. If the tension is too great, the brushes will wear and the commutator will heat unnecessarily.

4. When looking at the commutator on the d. c. machine, the motor should be so connected that the commutator will operate counter clockwise or backward.

5. The light controller or field rheostat which comes with the machine should be mounted at any convenient point in the booth. The lever should, as a general rule, point to the left. When the machine is first started, it may be necessary to move the lever a little toward the right. For less light, move the lever to the left side and for more light, move it to the right.

6. If the economizer is to be left turning when the arc is not burning, for any length of time, as would be the case when vaudeville is mixed with pictures, then stop the economizer by pulling the a. c. switch, or stop the generator current by installing a single pole knife switch in series with one of the wires running from the economizer to the light controller.

7. Please remember that the upper carbon should be ¾ in. cored and the lower 9/16 in. or ⅝ in. cored. Also remember if the upper carbon sits back of the lower, the arc is likely to climb up on front of the upper carbon and flare out and be very unsteady. To stop this, move the upper carbon slightly forward of the lower, then after the arc has steadied down, it can be drawn back while the arc is still burning, but don't let the upper crater burn with too much of a slant. To prevent this, move the upper carbon *forward* if it should be inclined to burn that way, as this will cause unsteadiness. Keep the arc ¼ to ⅜ in. long.

The wiring for the motor part of the economizer is standardized the same as for 5 h.p. motors, for the 25 to 70-ampere economizer. The wiring for the d. c. side should be of not less than No. 4 B & S gauge wire and the two wires which go from the field controller in the booth to the economizer should be No. 14 B & S gauge. In all cases where these machines are installed a special diagram of connection giving all details accompanies the economizer and the instructions given should be strictly followed. It is sometimes impossible to give exact information as to the position of the field controller lever, because in some places the line voltage is high and in others it is low. Then again the cycles may be below 60 or above 60, or may be higher or lower than the cycles for which the motor is made, no matter whether it be 25 or 60 cycles. In such cases, it is necessary to set the field controller at the point where proper results are obtained and it is generally well to try out with the field controller in lower position, or never over the center position anyway.

Many times, failure to secure steady arc is due to the use of too small carbons, and to the fact that the operators usually set the upper carbon a little back of the lower. With these machines, it is necessary to set the upper carbon a little ahead until the arc has been struck, then the upper carbon may be moved back to any desired position, so as to give the necessary exposed crater of the upper carbon point, but remember that if the upper carbon is moved back too far, the crater will be slanting and the arc will be blown out on the crater, causing it to flare against the upper part of the condensers and to burn very unsteady. If the carbons are held too close together, especially when new carbons are put in, the arc is likely to give a waving light, dying down and coming up again.

The remedy is to move the arm of the field controller to a lower point and separate the carbons a little bit. Never hold the carbons too close together for any length of time, as this will destroy the carbon points and cause unsteady light. It is better to let the arc be a little longer than a little too short, at least until you have secured perfectly steady burning. In a day's operation, an operator soon catches on to just the best way in each instance to secure proper results, and this information cannot be imparted in detail by any instructions from the maker.

For detailed instructions as to the care of the commutator, etc., see instructions given for d. c. to d. c. Hallberg Economizer. One thing of importance which should be remembered in the care of the machine is that it is always

Fig. 115

well to operate the brushes with the least spring tension which will give sparkless commutation. A stiff brush spring causes the brushes and commutator to wear excessively and at the same time is the cause of excessive heat at the commutator, due to friction. Stiff spring tension does no good and is a great detriment, therefore, take care that the spring is in the weakest notch, which will give sparkless commutation, and this is generally in the first or weakest notch.

The notches further back which incline to increase the tension of the spring should never be used unless the spring itself has become weakened by age. This is another point in which the judgment of the individual operator will have to be depended upon.

Fig. 115 illustrates a specially constructed switchboard for use in the operating room where the current is supplied by the Hallberg A. C. to D. C. Economizer. This particular illustration shows the double lamp control. The switchboard consists of a slate slab 3 ft. high by 2 ft. wide, 1¼ ins. thick, mounted on substantial angle iron frame with braces for the wall. At the top is the voltmeter, which indicates the voltage across the arc when one lamp is operating and the voltage across the generator when two lamps are operating. Below the voltmeter there are two ampere meters, one for Arc No. 1 and the other one for Arc No. 2. Immediately below the right hand ampere meter, there are three fuse connections, which protect the circuits. In conjunction with these fuses, there is a double throw switch which, when thrown to the left, puts the apparatus in position to operate two arcs at the same time. When it is desired to operate one arc only, this switch is thrown to the right.

At the bottom the field controller is mounted, by means of which the amperage at the arc may be controlled. At the right of the field controller, a single pole switch is provided. This switch is connected in series with the field controller and the object of it is to disconnect the field circuit from the armature connection. When this switch is open, the generator will not produce any current, but will generate immediately when the switch is closed.

In vaudeville houses, where pictures are run intermittently, this switch is of considerable value, or in fact in any theater where it is desired to give an intermission, because the switch may be opened, thereby saving a considerable amount on the power.

THE HALLBERG ECONOMIZER

Automatic Direct Current Type—Special Information and Instructions

A projector arc lamp operating with direct current at the arc requires between 45 and 55 volts potential drop across the arc for best results. It is safe to say that the average voltage drop across a direct current projector arc is 50 volts.

It is a well-known fact that the electric power companies do not supply current for use in theaters at a lower potential than 100 volts, and the average voltage is 110. In some localities, the lowest voltage obtainable is 220 volts, and again in a few places the only current available on which to operate a motion picture arc lamp is supplied at over 500 volts pressure.

Taking for granted that the average arc voltage required is 50, and that the minimum supply voltage is 110, it is evident that there is a loss representing 60 volts, usually consumed by a rheostat connected in series with the line and the arc.

If we consider a 30-ampere arc, this loss equals 30 amperes times 60 volts, or 1800 watts, which is the energy unnecessarily wasted in heat by the rheostat on 110-volt direct current circuit. One would think that the easy remedy would then be to provide a dynamo which would deliver 50 volts to the arc, thereby doing away with the losses, but unfortunately dynamos, as ordinarily constructed of such small size, are inefficient and comparatively expensive and besides would not operate the arc satisfactorily. Experience proves that about 75 volts is a practical voltage limit with ordinary dynamos or generators which must then be used together with a small rheostat connected in series with the arc, which introduces more loss in addition to the losses in the generator and the motor necessary to drive it that no particular economy is effected, and it further does not pay to install an ordinary motor generator for the operation of projector arc lamps.

With 220 volts supplied by the electric company, the loss in the rheostat is much greater, representing the difference between 50 and 220, or 170 volts times 30 amperes, which equals over 5 kilowatts. With 550 volts the loss is tremendous, representing the difference between 50 and 550, which equals 500 volts times 30 amperes, or 15 kilowatts.

With these figures before the operator, showing a loss on the direct current rheostat of 1.8 k.w. per hour on 110 volts, 5.1 k.w. on a 220-volt line and 15 k.w. on a 550-volt line, it becomes a necessity to save this great loss of electric energy. It is impossible to save all of it, because the electric arc requires a certain ballast, or steadying element, just like an engine requires a governor to prevent it from running away, as otherwise the arc would take all of the current the line wires could supply.

In order to secure this ballast, or steadying effect, the rheostat has been necessary, but some four years ago the writer developed a line of dynamo electric machines put on the market under the name of the "Hallberg" Automatic Direct Current Economizers, and the purpose of these machines, which are made for all circuits and conditions, according to the specifications of the operator, is to do away with the rheostat, not only on account of the current saved, but at the same time removing the heat from the rheostat, which is uncomfortable in any operating room, but at the same time actually improving the illuminating power of the arc, because of the absence of the arc mist or flame, which is always present when the arc is operating with a considerable supply voltage back of it.

It is true that this transformation of a high voltage into a lower voltage suitable for the operation of a projector arc cannot be accomplished without some losses, but in the "Hallberg" Economizer these losses have been reduced to a minimum, which the following table sets forth, and the figures in this table are guaranteed to be practically correct.

"HALLBERG" DIRECT CURRENT ECONOMIZER DATA

LINE INPUT				OUTPUT AT ARC			WATTS LOSS	EFFICIENCY
Line fuses required	Line volts	Line Amperes	Line watts	Arc Voltage	Arc Amp.	Arc watts		
20 A.	110	17	1870	50-55	30	1650	220	88%
10 A.	220	10	2200	50-55	30-35	1650	550	75%
5 A.	550	4	2200	50-55	30-35	1650	550	75%

Note: The D. C. to D. C. Economizer is also made in larger sizes as given for A. C. to D. C. with one or two lamp control.

The foregoing table is clear and explicit. It sets forth the size fuses required for the different line voltages; also the number of amperes taken from the line, as well as the number of watts per hour required from the line to produce 50 to 55 volts at 30 to 35 amperes at the arc, and by dividing the watts produced at the arc by the input in watts from the line, the efficiency figures for the economizer have been obtained.

Fig. 123 illustrates the general make-up of the 110-volt type economizer which, while being constructed along

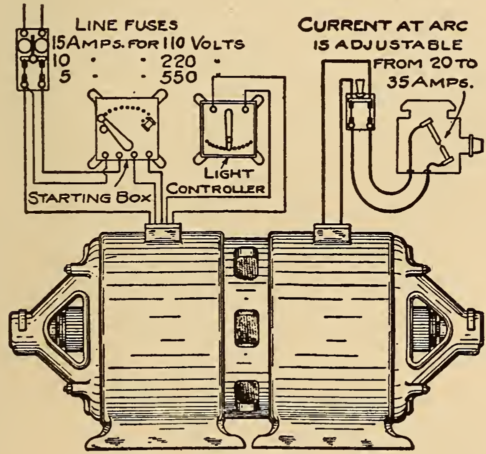


Fig. 123

the lines of a motor generator, is in the strict sense of the word only in part a motor generator. The principle involved permits the use of smaller and more efficient motor and generator than could possibly be had if the apparatus was a straight motor generator set. The 110-volt outfit is provided with an automatic starting box and light controller by means of which the operator can vary the amperes at the arc anywheres from 20 to 30 on the 25-ampere size; from 30 to 40 amperes on the 35-ampere size, and from 40 to 60 on the 50-ampere size. It is, of course,

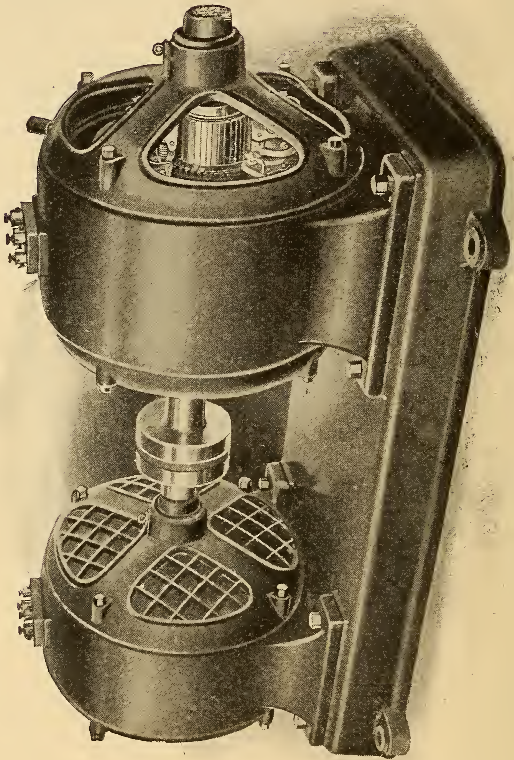


Fig. 124

possible to secure lower ampere output than specified as a minimum with any of the above machines, by the use of special light controllers which can be furnished upon request.

Fig. 124 illustrates the "Hallberg" direct current economizer as made for voltages ranging from 200 to 750, and this outfit is a straight motor generator set in which, however, the generator is of special construction, delivering a steady ampere flow to the arc without the use of a rheostat. The 200 to 750-volt outfit is also furnished complete with automatic starter and light controller, and besides this outfit has a pulley coupling between the motor and generator on which, in special cases, a belt may be placed for driving the economizer by means of an engine, which would make the economizer operate a motion picture arc just as it does when driven from an electric circuit, and at the same time from the high voltage side current can be taken for driving fan motors, or a limited number of lamps. This is an important feature and is of considerable value to an exhibitor who might have occasion to move the economizer from one place to another.

Another feature of this construction is that the low voltage side of the economizer is a separate unit which can be run as an ordinary dynamo by an engine ranging from 3 to 6 horsepower in capacity for the operation of a motion picture arc. The other half of the machine, representing the high-voltage side, is an ordinary electric motor which can be taken off the base in a few minutes' time and used as an electric motor, together with its automatic starter. These are points of economy which represent certain advantages to the purchaser of this class of apparatus.

It is not practical to give wiring diagrams showing the connections for these machines, because they vary for different voltages and currents, and as these machines are generally built to specifications to suit the individual operator or manager, it is best to depend upon the blueprint and diagram of connections which accompany the shipment, and if the instructions should be lost, another set can be readily obtained at the office of the manufacturer.

Fig. 125 illustrates the installation of two "Hallberg" direct current 40 to 50 amperes economizers operating on 110-volt direct current, delivering 40 to 50 amperes to the arc of each of two moving picture lamps in one of

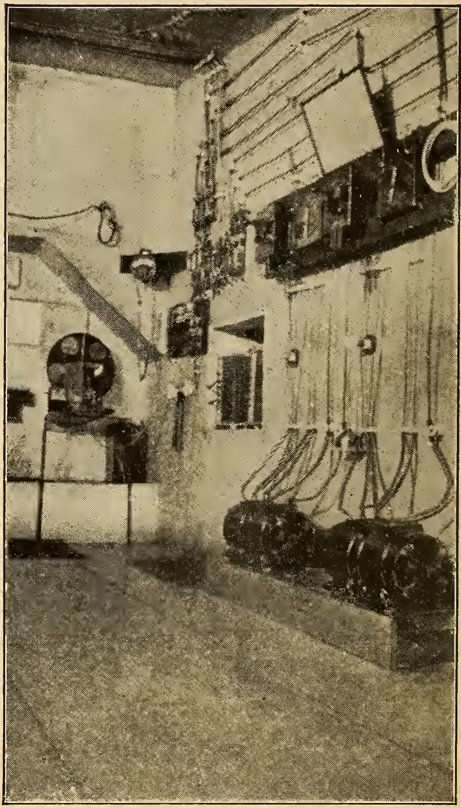


Fig. 125

Clune's Theaters at Los Angeles, Cal. The installation is complete, showing the switch and starting box with light controllers mounted back of the economizers, which are installed side by side on a foundation on which they did not have to be bolted down.

"HALLBERG" AUTOMATIC ELECTRIC D. C. ECONOMIZER

Instructions for Setting and Operating

Unpacking and Setting Up.—The machine should be unpacked carefully and installed in a dry, cool place where it will be free from dust and easily accessible for inspection and care of brushes and oiling. If the operating room is large enough, the machine can, of course, be put there.

Connections.—All connections should be made as shown on the wiring diagram sent with each machine. They must be clean and tight. Fuses should not have a higher capacity than that given on the diagram.

Brush Tension.—After the machine has been properly set and connected, rotate the armature by hand and examine each and every carbon brush, to make sure that it moves freely, without the slightest friction in the brush holder which guides it. Make sure that the flexible copper cable, or pigtail, as it is called, is properly clamped by the screw in the brush holder casting provided for that purpose. When the brush is in proper condition and moves freely in the holder, the next point to be looked after is the spring tension which pushes the brush against the commutator. This spring tension should be *just enough* to press the brush evenly but firmly against the commutator. The brush tension spring is adjustable by putting the end of it in the different notches provided for it in the brush holder casting, and any degree of tension can be had by using the different notches. When the brush is new and long, it may be proper to run it in the first or weakest notch. As the brush wears away and gets shorter, the spring unwinds slightly and gets weaker, therefore it may be proper to move it in the next notch to increase the strength of the spring, but the judgment and experience of the operator will have to determine the brush tension required. It is sufficient to state here that it is always well to run with as light brush tension as possible to still secure sparkless operation. Dirt, overload and too light brush tension causes sparking. Excessive wear of the commutator and brushes is caused by the brush tension being too great. A happy medium is the proper thing.

Oiling.—The oil chambers should contain enough oil to give the rings a good dip. The oil level will be seen in the gauge on the sides of the bearings and should be nearly at the top of the gauge. When starting the machine, lift oil chamber covers and see that the oil rings are turning freely and carrying oil to the shaft. The old oil should be drawn off by unscrewing the drainage plug at bottom of the bearing every month or two, and replaced with new oil. Use only light machinery or dynamo oil. If the oil is too heavy, the rings will not revolve and the bearings will not be lubricated. If the oil is too light the bearings will run hot.

Setting of Brushes.—Machines are shipped from the factory with the brush holders and brushes properly set. The position of the brushes is approximately half way between the poles. In the motor, they are placed one or two segments back (that is, against the direction of rotation) of the exact middle, or neutral point, while in the generator they are set one or two segments forward. The brush holders should be placed on the studs, so that the brushes will not run in the same line on the commutator. This will help to avoid grooving.

Starting Set.—First see that the starting box lever has moved back to the off position. If there is a regulating rheostat on the motor end, its handle should be moved as far as possible in a counter clock-wise direction. If there is one on the generator end, its handle should be moved as far as possible in a counter clock-wise direction. Close the main switch and move the lever of the starting box over the contacts, taking about one second for each, until it is against the magnet which will hold it. If the set has not started when the fourth contact point is reached, open the main switch and ascertain the trouble. When the set is running, the current may be adjusted by means of the regulating rheostats.

Stopping Set.—Open the main switch and let the starting box operate itself. The lever will be released when the motor has slowed down, when it will fly back to the "off" position. If the contacts become rough and prevent the lever from moving fully back, they should be cleaned with sandpaper. The lever should never be fastened or allowed to stick at an intermediate point.

Care of Brushes and Commutator.—When starting, and once or twice a day, the commutator should be rubbed with a piece of cloth or waste having a few drops of ordinary sperm or machine oil on it. This is sufficient lubrication, and the commutator ought to assume a dark brown polish and run for an indefinite period with very little attention. Sandpaper should be used sparingly and only if the commutator has become rough by reason of sparking caused by dirt. See that the brushes are being held properly against the commutator by their springs, and that there is no friction preventing the brush from sliding firmly and evenly on the commutator. Make sure all brushes are *long enough,* as otherwise a short brush will hang up and make poor contact at the commutator, causing sparking, overheating and consequent injury.

CHAPTER XIII

Westinghouse-Cooper Hewitt Rectifiers.

The advantages of the direct-current arc lamp are well known. The light is steady and does not flicker. It is all thrown forward because the intense heat is concentrated on one carbon. Focusing is a comparatively simple matter.

By means of Westinghouse Type AL Cooper Hewitt rectifier outfit, direct-current arc lamps can be operated on an alternating current lighting circuit, and often more economically than alternating-current lamps. This is not strange when one considers that the direct-current arc requires only three-fifths as much current and that all of the power lost in heat in "resistance ballast" is saved by "reactance balance" in the rectifier. This avoids the disagreeable heat of the rheostats as well.

The outfit consists of a Cooper Hewitt mercury rectifier bulb and suitable stationary regulating apparatus, all contained in a ventilated iron case. The rectifier bulb changes the alternating current supplied into direct current.

The rectifier starts automatically when the lamp carbons are brought together, and stops when the switch is opened or the carbons separated far enough to break the arc.

There is no machinery to get out of order, no dirt, or noise.

Standard Type AL outfits are made for 110 and 220-volt, 60-cycle, alternating-current circuits and for 30, 40 and 50-ampere direct current. For ordinary moving picture work a 30-ampere arc has been found sufficient, while for extra large screens or colored pictures 40 or 50 amperes has sometimes been found desirable.

The arc voltage is regulated between 48 and 58 volts. The life of the bulb, the only part that requires renewal, averages 500 hours or more, and an allowance is made for the return of the terminals. While outfits for 60 cycles are standard because 60-cycle circuits are most common, similar outfits for other frequencies are furnished when required. On frequencies lower than 60 cycles, such as 25 cycles, the alternating-current flicker becomes so pronounced as to make a d. c. arc practically necessary.

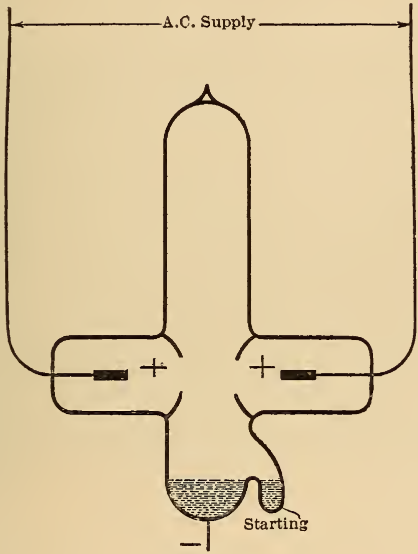


Fig. 116

PRINCIPLES OF OPERATION

The mercury rectifier consists essentially of a hermetically sealed glass bulb filled with mercury vapor and provided with four electrodes. The two upper electrodes (Fig. 116) are of graphite or other suitable material and the two lower of mercury. The graphite electrodes are the *anodes;* the main mercury electrode is the *cathode;* and the small one is the *supplementary starting* electrode. The mercury pools of the two lower electrodes are not in contact when the bulb is vertical, but the bulb is so mounted that it can be tilted to bring these two pools temporarily in contact for starting.

The bulb contains highly attenuated vapor of mercury, which like other metal vapors, is an electrical conductor under some conditions. The anodes are surrounded by this vapor. Current can readily pass from either of the solid electrodes to the mercury vapor and from it to the mercury electrode, but when the direction of flow tends to reverse, so that the current would pass from the vapor to the solid electrode, there is a resistance at the surface of the electrode which entirely prevents the flow of current. The alternating-current supply circuit is connected to the two anodes as shown in the diagram, Fig. 116, and as the electrodes will allow current to flow in only one direction and oppose any current flow in the opposite direction, the pulsations of the current pass alternately from one or the other of the anodes into the mercury. As these currents cannot pass from the vapor into either anode, they are constrained to pass out all in one direction through the mercury electrode, from which they emerge as a uni-directional current. The anodes of the rectifier thus act as check valves, permitting current to pass into the mercury vapor, but preventing it from passing from the vapor to the solid electrodes.

Before the bulb starts to rectify, there is a high resistance at the surface of the mercury, which must be broken down so that the current can pass. This surface resistance is called the cathode resistance, and it acts like an insulating film over the entire surface of the mercury. This film must be punctured, or in other words, the resistance must be overcome, before any current can pass. When once started, the current will continue to flow, meeting with practically no resistance as long as the current is interrupted. Any interruption of the current, however, even for the smallest instant of time, permits the cathode resistance to re-establish itself, which stops the operation of the bulb.

In order to overcome this resistance the bulb is tilted so that the space between the main and supplementary mercury electrodes is bridged by the mercury. Current then passes between the two mercury electrodes from the source of e. m. f., and the little stream of mercury which bridges the space between the electrodes breaks with a spark as the bulb is returned to a vertical position. This spark breaks down the negative electrode resistance, after which the rectifier will continue to operate indefinitely as long as the current supply is uninterrupted and the direct-

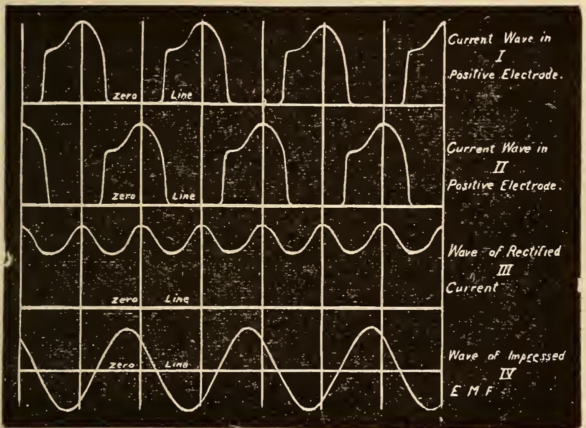


Fig. 117

Diagram Showing Current Waves and Impressed Electromotive Force

current load does not fall below the minimum required for the arc.

The action of the rectifier will be better understood by reference to the accompanying diagram, Fig. 117, of current waves and impressed electro-motive force. It should be emphasized that the whole of the alternating-current waves on both sides of the zero line is used. The two upper curves in the diagram show the current waves in each of the two anodes, and the resultant curve III represents the rectified current flowing from the cathodes.

Curve IV shows the impressed alternating current e. m. f. It is evident that if the part of the wave below the zero line were reversed, the resulting current would be a pulsating direct current with each pulsation varying from zero to a positive maximum. Such a current could not be maintained by the rectifier, because as soon as the zero value was reached the negative electrode resistance of the rectifier would be re-established and the circuit would be broken. To avoid this condition, reactance is introduced into the circuit, which causes an elongation of current waves so that they overlap before reaching the zero

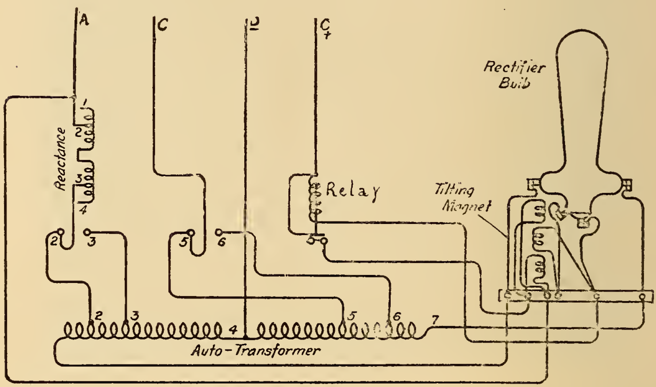


Fig. 118

value. The overlapping of the rectified current waves reduces the amplitude of the pulsations and produces a comparatively smooth direct current as shown in curve III.

The complete circuit of a type A1 rectifier outfit is shown in Figs. 118 and 119. The alternating current supply circuit is connected at A and C, which run to taps 2 and 5 on an auto-transformer whose terminals 1 and 7 are connected to the anode terminals of a rectifier bulb. From the lower cathode terminal of the bulb the current passes through lead C to the lamp which is connected to D and C, and the circuit is completed through the lead D, and the relay to the middle point of the auto transformer.

Bringing the lamp carbons together closes the following circuit: A. C. terminal C to tap 5, through auto transformer to tap 4, through lead D to lamp, through lamp to terminal C, through contacts of relay to tilting magnet, through tilting magnet to tap on lead A. This excites the tilting magnet and tilts the bulb so the two mercury pools unite. At the same time the alternating current in the tilting magnet induces a voltage in the small starting winding wound with it, which causes current to flow be-

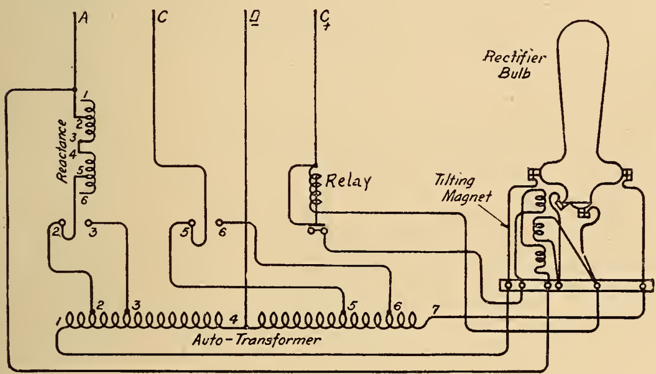


Fig. 119

tween the mercury pools as soon as they unite. This current acts like a short-circuit on the tilting magnet, and the bulb rights itself, causing a spark which breaks down the cathode resistance and starts current through the bulb from the main anodes. This current flows through the relay coil and opens its contacts which opens the tilting magnet circuit.

Figs. 120 and 121 show diagrams of connections of the 50-ampere outfits, the operations of which are similar to those of the 30-ampere.

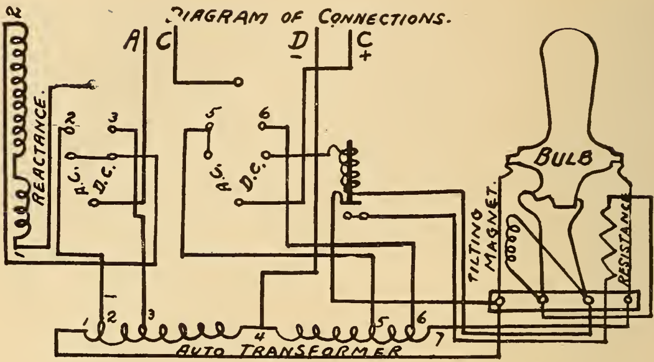


Fig. 120

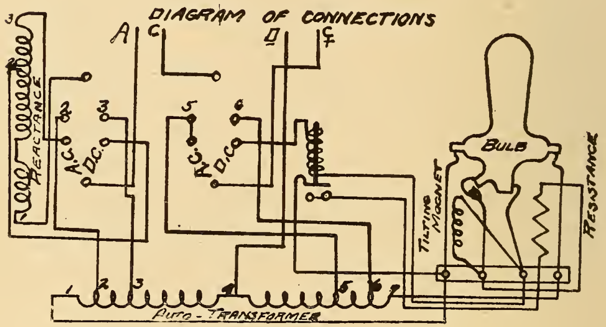


Fig. 121

INSTRUCTIONS FOR INSTALLING AND OPERATING

To Connect Rectifier.—Connect the rectifier terminals marked A and C to an alternating-current supply circuit of the voltage and frequency stamped on the rectifier name-plate. The outfit should be connected through a switch and fuses of proper capacity, as follows:

AL RECTIFIERS

Volts.	D. C. Amperes.	Line Fuse Capacity Amperes.
110	30	70
220	30	40
110	40	110
220	40	65
110	50	150
220	50	85

Connect leads marked D— and C† to the lamp circuit, taking account of proper polarity. Place bulb carefully in holder, and attach spring clips as per diagram.

To Start Arc, close carbons together until a bright glow shines between them and then pull apart until the desired light is obtained. Never hold the carbons together longer than necessary, as it may injure the bulb.

To Extinguish Arc, pull carbons apart until arc breaks, or open line switch.

For various primary voltages connect leads to binding posts as per following table. The primary voltage here referred to is that existing while the oufit is in operation and not that on open circuit.

For	110 or 225	volts,	primary,	connect	3 and 5
"	110 or 220	"	"	"	3 and 6
"	108 or 215	"	"	"	2 and 5
"	105 or 210	"	"	"	2 and 6

CHAPTER XIV

Isolated Electric Lighting Plants

A WORK of this kind would be incomplete without some reference to individual or isolated electric generating plants.

It goes without saying that direct current with good regulation, at the proper voltage, and at a reasonable price, is the ideal current, but it is equally true that the conditions covered by the above apparently simple requirements are almost never met with.

Alternating current is not so well suited for moving picture work, and under many conditions is almost intolerable.

In A. C. the direction of flow is constantly reversing, the arc being actually extinguished and re-formed twice during each complete alternation. This allows the carbon points to partially cool, the result being that it is impossible to secure as large a volume of light from A. C. as from D. C. current, using the same amount of energy.

In general, it may be stated, roughly, that from 40 to 50 per cent. more current is required with A. C. than with D. C. This means that where in a given instance 30 amperes of D. C. would suffice, it might take 45 to 50 amperes of A. C.

Each period of alternation is known as a cycle, and the number of cycles per second denotes the frequency of current. If of low frequency (60 cycles may be considered as being low) the light is very unsteady, under many conditions almost intolerable, and the situation is, of course, aggravated by poor regulation. An arc operated with A. C. is always more or less noisy; the higher the frequency, the noisier.

In many places where alternating current only may be obtained, many of the larger show-houses use A. C. to D. C. sets to secure direct current. While the apparatus itself is somewhat expensive, this expense is often warranted by the saving of current and the obtaining of a superior light.

Now, as to regulation. In very many small towns and villages the lighting service is an adjunct to a grist mill, planing mill, or some sort of factory, and the producing of current for sale is a secondary consideration, a sort of by-product as it were. The power plants owned by such concerns are rarely ever designed for lighting, and the result is that there is no regulation whatever. Sometimes there is no evening or night current furnished, excepting specially and at an excessive cost.

Where, on the other hand, as is often the case, the plant is owned by the municipality or village, and used only for street and house lighting, the show owner is unable to get current in the daytime, and this may cut into his possible revenue to the extent of twenty-five to thirty-five per cent.

Continuing the matter of regulation, it is true that in the majority of small cities and towns the central station equipment is apt to be archaic, inferior, or poorly looked after. From a recent number of the "Electrical World" I quote:

"We have occasionally remarked on the very poor voltage regulation which commonly exists among isolated plants. Probably a thorough investigation among small central station companies would reveal the condition as almost deplorable. Lamp salesmen who have made it a point to investigate regularly tell some surprising stories as to the lack of regulation. Frequently it has been found that plants giving service nominally at 110 volts are found to be actually delivering *all the way from* 90 *to* 130 *volts.*"

We may now consider the matter of voltage. The actual voltage required at the arc is from, say 40 to 55 volts, variations being caused by the amperage of the arc as well as by the quality and density of the carbons used, and there must be in series with the arc suitable resistance or ballast to maintain a constant, quiet arc. The arc-resistance decreases with increased temperature, so that without a suitable ballast the amperage would increase indefinitely on a constant potential circuit. Therefore, there must be an allowance of not less than twenty-five per cent. of the arc voltage to be absorbed by the resistance. Thus it will be understood that a current of 60 volts may be sufficient, and 70 volts ample, for almost any condition.

Current as ordinarily obtained from lighting companies varies, being rarely less than 110 volts, and from that up to 220. From what is stated above, it will therefore be understood that all current above 50 volts is absorbed and wasted in the rheostat, so that when one is paying for 220-volt current the loss is very great.

As a not altogether unusual example. I may cite an instance which recently came under my notice, of a theater owner who had been obtaining current from a local company whose output was 220 volts alternating current. The arc was controlled by a rheostat and consumed slightly over 50 amperes. This was charged for at the rate of 8 cents per k.w. unit. The consumption of 50 amp. at 220 v. is 11 k.w., which at the perhaps not excessive price of 8 cents made the running cost 88 cents per hour. After some study and investigation, a small gas engine driven plant with 65-volt generator was purchased and installed, with most gratifying results. While the cost of current was reduced from 8 to less than 4½ cents per k.w., this was, however, by far the least of the saving. With direct current the consumption at the arc went down to 33 amperes, which at 65 volts made a consumption of but little over 2 k.w., or a cost per hour of less than 10 cents as compared with 88.

Taking up the subject of price, this is a most serious question. The cost of electric current is an important item of expense in a picture theater. It is not at all unusual to find instances in which theaters using from 1,000 to 2,000 k.w. per month are being charged at the rate of 8 or 9, or even up to 15 cents per unit. The theater owner may reduce this expense by owning his own electric generating plant.

As a matter of fact, there are hundreds of privately-owned small plants in use at the present time, and the chief aim of this article is to be somewhat helpful to the reader whose opportunities for gaining an intimate knowledge of the subject are limited.

While it is not within the province of a writer of a work of this kind to recommend any one particular make of plant, or to criticize and condemn any other particular make, he is well within his rights in setting forth certain conclusions which are the result of many years' experience with internal combustion engines and electrical apparatus.

The first thing to be considered is the gas or gasoline engine, and it may be well to say right here that the type of engine in common use is entirely unsuitable for making electric light. Nine-tenths of all the engines sold for many years have been—and are—of the "Hit-or-miss" or constant charge type.

When running at full power such an engine takes a full charge every cycle (four strokes). When running at half power it will take a charge and miss the next, or two charges and miss the next two or three, and so on. The result is that the speed varies, speeding up after charges and slowing down before, the rate of speed varying from as little as 5 to as much as 20 per cent. This variation in speed is not serious where such an engine is used for farm or factory purposes, but is quite "impossible" when electric light is to be made. Many makers of such engines equip them with extra heavy flywheels, which remedy the trouble somewhat, and, while this may—and does—sometimes prove fairly satisfactory, it is only in the case of large engines with very heavy flywheels. I have never seen an engine of this type under 50 horsepower that even with the heaviest flywheels gave really satisfactory results.

The reason for the existence of this type of engine is that it is cheap and easy to build. Having a mixing valve in place of carburetor, there are no carburetion difficulties to overcome, and, as stated previously, for ordinary power work, close regulation and evenness of speed is not a requisite. In projection work, however, the moment an engine runs below speed, the lights dim. If much above speed, the lamps are burned out, or the life is shortened. The speed of the engine changing constantly makes a variable light, which is most unsatisfactory and annoying.

The only type of engine suitable for electric work is what is known as the graduated charge or "throttling" type. In this engine there is no hit-or-miss effect, the engine taking a charge for every cycle of operation, and the charge being automatically graduated to the load. While, as stated above, this is the only type of engine suitable for electric work, all so-called throttling engines are not capable of making a good light, as many manufacturers of rather indifferent hit-or-miss engines have a habit of substituting an inefficient governor mechanism and mixing valve, and recommending them for electric light work. As a matter of fact, there are too many novices in the gas engine business, and so far as actual knowledge is concerned, a man may have been in the gas engine manufacturing business for twenty years and still remain a novice.

As stated elsewhere, it is not my province to recommend any one particular make of plant, but I am justified in naming here a few old, reliable, well-established concerns which have made a specialty of electric lighting plants. This information is gratuitous, and the list covers the only firms I know of at the present time, viz.:

Brush (C. A. Strelinger Co., Detroit),
Nash (National Meter Co., New York),
Westinghouse (Westinghouse Machine Co., Pittsburgh),
General Electric Co. (Schenectady),
Otto (Philadelphia).

All of the above concerns make direct-connected outfits, and a few words here about the advantages of direct connection may not be out of place.

First of all, the outfit is much more compact, and seldom takes up more than one-quarter of the room of a belted outfit. Furthermore, there being no belt strain and friction on the bearings of both engine and dynamo, it may be depended upon to give from 10 to 15 per cent. more power. Naturally, a direct-connected outfit is longer-lived, saving as it does much friction wear on both engine and generator shaft and bearings. It is necessarily a higher-priced form of construction. First, on account of the sub base and expense of connecting; second, on account of using a much slower speed, and consequently higher-priced generator. However, this difference is overcome to a considerable extent by the absence of cost of belts and their care, extra cost of foundation, and much longer life of the outfit. A final distinct advantage of the direct-connected plant lies in the fact that the outfit is set up and tested as a whole, and goes to the purchaser as a complete unit, whereas in belted outfits they are usually considered separately, and not once in a dozen cases are they ever tested together. Anyone who has had much to do with either gas engines or electric generators knows that such machines have their own little characteristics, and when one is adapted and fitted to the other, after thorough testing out, the results are invariably superior.

Having had many inquiries and questions about two-cycle engines, I feel that some readers might like to have a little information in regard to this type. As Mr. George Fitch, the noted humorist, writes: "Nobody can ever hope to learn the true inwardness of the two-cycle engine." I know that they are sold in large numbers for use in boats; that the exhaust has a pervading odor of unburnt gases; that the fuel consumption is said to be from 50 to 100 per cent. greater than that of a four-cycle engine; and, finally, that starting out with flying colors in the automobile field some eight or ten years ago, they have died an inglorious death—in that line.

The manufacturing of electric generators in this country is in the hands of perhaps not more than forty concerns. Ten of these produce perhaps no less than ninety per cent. of the electric generators and motors sold in this country, and of these ten concerns it may truthfully be said that the product of any—or all—of them is excellent.

In the manufacture of gas engines the conditions are quite different. There are no less than two hundred and fifty concerns engaged. Not more than ten per cent. of these concerns turn out a strictly first-class product, and, unfortunately—for the user—the product of some of the largest and most advertised is the least desirable as far as quality is concerned.

In closing this chapter, I might suggest that the purchaser of an electric lighting plant will do well to con-

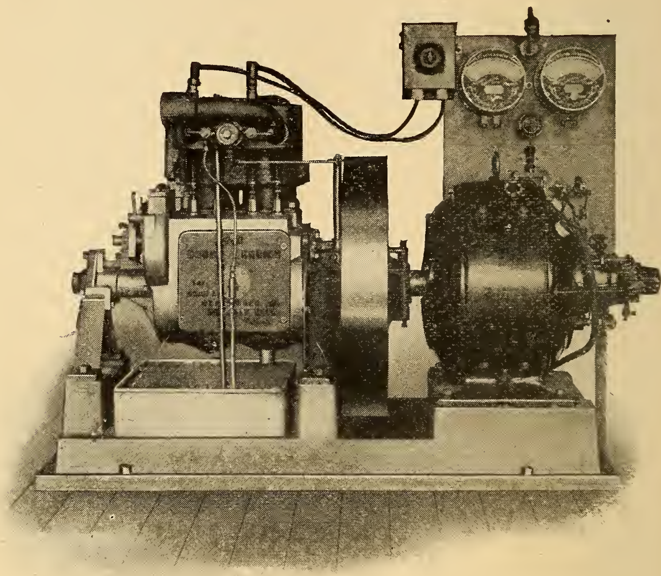


Fig. 122

sider carefully and take into account the quality of equipment and accessories that the manufacturer includes. I refer to the switchboard and instruments, the ignition system, such as batteries and coils—or magneto, if that be the system—tanks, tools, and so forth.

Fig. 122 illustrates the Brush Electric Lighting Set, which is one of those recommended as thoroughly reliable and of high efficiency and guaranteed to give service. The illustration shows the engine directly connected to electric generator of the highest quality, and there is furnished with this outfit a switchboard containing the necessary controlling switches, field regulator and Weston volt and ampere meter, all complete.

The plant illustrated is about 5 k.w. capacity. There is also a smaller outfit made with single-cylinder engine of smaller type which delivers only 2 k.w., and is of just the right size for traveling shows. This type of engine may also be had in larger capacity when both motion picture arcs and incandescent lights are to be operated at the same time. The cost of these plans is necessarily higher than would be the cost of inferior make engines and generators with a fewer number of accessories, or with accessories of poorer quality, but the extra charge for this equipment will more than pay for itself in a very short time. An outfit of this sort is of no use whatever to an exhibitor, unless it first of all is thoroughly reliable, so that in making your selection, don't let price influence you. If you do, you will come to sorrow in the long run, and I could point to hundreds of plants where cheap engines and dynamos with inferior fittings have been installed, which have become worthless in six months or a year's time.

Practical Suggestions

Data and Tables for Projection

TO FIND THE POSITIVE CRATER OF A D. C. ARC

Whenever using direct current, it is necessary that the positive wire be connected to whichever carbon is to maintain the positive crater, and in ordinary projector lamps the upper carbon should be positive. Connect the wires, strike the arc, let it burn from 10 to 20 seconds, pull the switch, and if the upper carbon is hotter than the lower your line wires are properly connected; if not, reverse the connections at the arc lamp.

With flaming arc lamps on direct current, proceed in a similar manner, and make sure that the larger carbon is the positive or the reddest after the test from 10 to 20 seconds. If the arc is maintained longer than this period, the carbon points are both too hot to decide which shows the most heat, hence the advice for a short period of test. With alternating current there is, of course, no necessity for connecting the lead wires in any particular manner, as the current reverses and there is no definite positive pole.

MACHINE SWITCHES

In addition to the regular switch on the machine, each stereopticon, spot-light or moving-picture machine should be protected by an approved double-pole switch, equipped with fuses of approved type, keeping in mind that the fuses and the switch should be so connected that the fuses are always on the line side of the switch. It is readily understood that, if the fuses are on the machine side, an accidental short-circuit of the switch-blades would blow the main fuses in some other part of the building, causing serious delay and inconvenience.

CONNECTING MOVING PICTURE MACHINES AND STEREOPTICONS FOR TRAVELING EXHIBIT

Never attempt to make connections for the above class of apparatus until you have carefully investigated the supply wires, transformers, meters, fuses and switches and other accessories, to ascertain if they are of sufficient capacity to stand the increased load which will be applied through the connecting of such lamps. If you are in doubt, don't "copper" fuses.

Don't put a jumper around the meter or connect ahead of the meter.

Avoid risk and possible trouble and expense by consulting the superintendent of the electric lighting company, or, if supplied by a private plant, consult the electrician or engineer in charge. You cannot afford to jeopardize the success and safety of your performance by using makeshift methods.

SIZE OF WIRE FOR STEREOPTICON, SPOTLIGHT AND MOTION PICTURE MACHINES

The Board of Fire Underwriters issue rules which can be had for the asking, setting forth the proper size and kind of fuses, switches, wires and cables which may be safely used for stereopticon, spotlight and motion-picture machine lamps, but for the convenience of those who do not know the rules, I will make the brief statement that No. 6 B. & S. wire or cable is the smallest which is officially approved for a circuit supplying one such lamp requiring from 25 to 45 amperes from the line. Where the Hallberg Economizer or a similar device is used, the circuit wires may be smaller when properly protected by fuses, but between the economizer and the arc lamp, asbestos-covered copper cable of at least No. 6 B. & S. gauge must be used. See also page 239.

CURRENT REQUIRED FOR MOTION PICTURE PROJECTION

Where direct current is supplied, 25 amperes is about the minimum amount of current which can be used for ordinary projection. Where the distance from lens to screen is comparatively great, or where a large picture is required, or in cases where an extra brilliant picture must be shown, from 30 to 60 amperes is necessary.

With alternating current supply, for ordinary projection, 40 amperes is about the minimum, and as a general rule 45 to 50 amperes is required for good results. In special cases where the projection is comparatively long, or picture is large, or extra brilliancy is desired, as much as 70 amperes may be required.

CURRENT REQUIRED FOR STEREOPTICON PROJECTION

With direct current, 10 to 15 amperes gives sufficient illumination for ordinary stereopticon work, but for professional, high-class exhibit as much as 25 amperes may be required for large pictures and long distances. With alternating-current supply, 15 amperes is the minimum, and for best results as much as 35 amperes is required.

REDUCTION IN SIZES OF LINE WIRE, FUSES AND SWITCHES WITH THE HALLBERG ECONOMIZER

When the "Hallberg" is installed, the maximum amperes required on 110 volts direct current is 25, and with alternating current, 30 amperes. With 220 volts direct current, 12 amperes, and with alternating current, 15 amperes. With 500 volts direct current, 6 amperes, and with alternating current, 7 amperes.

It is, of course, understood that where the "Hallberg" or similar device is not installed, this reduction in the size of line wires, fuses and switches is not permissible, as they must be of the full ampere capacity required by the arc under maximum conditions.

ALLOWABLE CARRYING CAPACITY OF COPPER WIRES

(Fire Underwriters' Rule)

B & S. G.	TABLE A RUBBER INSULATION AMPERES	TABLE B OTHER INSULATION AMPERES	CIRCULAR MILS
18	3	5	1,624
16	6	10	2,583
14	15	20	4,107
12	20	25	6,530
10	25	30	10,380
8	35	50	16,510
6	50	70	26,250
5	55	80	33,100
4	70	90	41,740
3	80	100	52,630
2	90	125	66,370
1	100	150	83,690
0	125	200	105,500
00	150	225	133,100
000	175	275	167,800
0,000	225	325	211,600
CIRCULAR MILS			
200,000	200	300	
300,000	275	400	
400,000	325	500	
500,000	400	600	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above table.

The carrying capacity of Nos. 16 and 18 B. & S. gauge wire is given, but no smaller than No. 14 is to be used, except as allowed under rules for fixture wiring.

DIAMETER, WEIGHTS AND RESISTANCE OF COPPER WIRE

No. B. & S.	Diameter Mils	Area Circular Mils	Weight, Bare Wire Pounds per 1,000 Feet	Weight, Bare Wire Pounds per Mile	Resistance at 75° Fahrenheit		
					Ohms per 1,000 Feet	Ohms per Mile	Feet per Ohm
0000	460.000	211600.0	640.73	3383.04	.04904	.25891	20939.2
000	409.640	167805.0	508.12	2682.85	.06184	.32649	16172.1
00	364.800	133079.0	402.97	2127.66	.07797	.41168	12825.4
0	324.950	105592.5	319.74	1688.20	.09827	.51885	10176.4
1	289.300	83694.5	253.43	1338.10	.12398	.65460	8066.0
2	257.630	66373.2	200.98	1061.17	.15633	.82543	6396.7
3	229.420	52633.5	159.38	841.50	.19714	1.04090	5072.5
4	204.310	41742.6	126.40	667.38	.24858	1.31248	4022.9
5	181.940	33102.2	100.23	529.23	.31346	1.65507	3190.2
6	162.020	26250.5	79.49	419.69	.39528	2.08706	2529.9
7	144.280	20816.7	63.03	332.82	.49845	2.63184	2006.2
8	128.490	16509.7	49.99	263.96	.62849	3.31843	1591.1
9	114.430	13094.2	39.65	209.35	.79242	4.18400	1262.00
10	101.890	10381.6	31.44	165.98	.99948	5.27726	1000.50
11	90.742	8234.11	24.93	131.65	1.26020	6.65357	793.56
12	80.808	6529.94	19.77	104.40	1.5890	8.39001	629.32
13	71.961	5178.39	15.68	82.792	2.0037	10.57980	499.06
14	64.084	4106.76	12.44	65.658	2.5266	13.34050	395.79
15	57.068	3256.76	9.86	52.069	3.1860	16.8223	313.87
16	50.820	2582.67	7.82	41.292	4.0176	21.2130	248.90
17	45.257	2048.20	6.20	32.746	5.0660	26.7485	197.39
18	40.303	1624.33	4.92	25.970	6.3880	33.7285	156.54
19	35.890	1288.09	3.90	20.594	8.0555	42.5329	124.14
20	31.961	1021.44	3.09	16.331	10.1584	53.6362	98.44
21	28.462	810.09	2.45	12.952	12.8088	67.6302	78.07
22	25.347	642.47	1.95	10.272	16.1504	85.2743	61.92
23	22.571	509.45	1.54	8.145	20.3674	107.540	49.10
24	20.100	404.01	1.22	6.4593	25.6830	135.606	38.94
25	17.900	320.41	.97	5.1227	32.3833	170.984	30.88
26	15.940	254.08	.77	4.0623	40.8377	215.623	24.49
27	14.195	201.50	.61	3.2215	51.4952	271.895	19.42
28	12.641	159.80	.48	2.5548	64.9344	342.854	15.40
29	11.257	126.72	.38	2.0260	81.8827	432.341	12.21
30	10.025	100.50	.30	1.6068	103.245	545.133	9.686
31	8.928	79.71	.24	1.2744	130.176	687.327	7.682
32	7.950	63.20	.19	1.0105	164.174	866.837	6.091
33	7.080	50.13	.15	.8014	207.000	1092.96	4.831
34	6.304	39.74	.12	.6354	261.099	1378.60	3.830
35	5.614	31.52	.10	.5039	329.225	1738.31	3.037
36	5.000	25.00	.08	.3997	415.047	2191.45	2.409
37	4.453	19.83	.06	.3170	523.278	2762.91	1.911
38	3.965	15.72	.05	.2513	660.011	3484.86	1.515
39	3.531	12.47	.04	.1993	832.228	4394.16	1.2020
40	3.144	9.88	.03	.1580	1049.718	5542.51	.9526

FIGURING PROPER SIZE OF WIRE

For figuring proper size of wire for any given number of amperes and distances of a building, the rule is:

$$\frac{C \times D \times 21}{\text{Loss}} = \text{Circular Mils}$$

In this formula, C equals current in amperes, D equals distance in feet between the source of supply and the load.

Explanation: Suppose we have a moving picture arc requiring 40 amperes and the distance between the source of supply and the moving picture machine is 30 feet; also taking for granted that the loss figures at 1% for this class of wiring within buildings, then the formula will be made up as follows:

$$\frac{40 \times 30 \times 21}{1} = \text{Area in } 25{,}200 \text{ circular mils.}$$

If we will refer to the above table, we will find that the nearest size wire would be No. 6 B & S, which measures 26,250.5 circular mils, and this will be the correct size wire to use.

The foregoing formula can be used for any capacity and for any distance, and by its use in conjunction with the foregoing tables, giving the gauge of wire and its corresponding area in circular mils, it is very easy to figure the size wire required.

TABLE SHOWING THE DIFFERENCE BETWEEN WIRE GAUGES

NO.	AMERICAN OR BROWN & SHARPE'S	OLD ENGLISH OR LONDON	BIRMINGHAM OR STUBS	W. & M. AND ROEBLING	NEW BRITISH STANDARD	U. S. STANDARD
0000	.460	.454	.454	.393	.400	.406
000	.40964	.425	.425	.362	.372	.375
00	.36480	.380	.380	.331	.348	.344
0	.32495	.340	.340	.307	.324	.313
1	.28930	.300	.300	.283	.300	.281
2	.25763	.284	.284	.263	.276	.266
3	.22942	.259	.259	.244	.252	.250
4	.20431	.238	.238	.225	.232	.234
5	.18194	.220	.220	.207	.212	.219
6	.16202	.203	.203	.192	.192	.203
7	.14428	.180	.180	.177	.176	.188
8	.12849	.165	.165	.162	.160	.172
9	.11443	.148	.148	.148	.144	.156
10	.10189	.134	.134	.135	.128	.141
11	.09074	.120	.120	.120	.116	.125
12	.08081	.109	.109	.105	.104	.109
13	.07199	.095	.095	.092	.092	.0938
14	.06408	.083	.083	.080	.080	.0781
15	.05706	.072	.072	.072	.072	.0703
16	.05082	.065	.065	.063	.064	.0625
17	.04525	.058	.058	.054	.056	.0563
18	.04030	.049	.049	.047	.048	.0500
19	.03589	.040	.042	.041	.040	.0438
20	.03196	.035	.035	.035	.036	.0375
21	.02846	.0315	.032	.032	.032	.0344
22	.025347	.0295	.028	.028	.028	.0313
23	.022571	.027	.025	.025	.024	.0281
24	.0201	.025	.022	.023	.022	.0250
25	.0179	.023	.020	.020	.020	.0219
26	.01594	.0205	.018	.018	.018	.0188
27	.014195	.01875	.016	.017	.0164	.0172
28	.012641	.0165	.014	.016	.0148	.0156
29	.011257	.0155	.013	.015	.0136	.0141
30	.010025	.01375	.012	.014	.0124	.0125
31	.008928	.01225	.010	.0135	.0116	.0109
32	.00795	.01125	.009	.013	.0108	.0102
33	.00708	.01025	.008	.011	.010	.0094
34	.0063	.0095	.007	.010	.0092	.0086
35	.00561	.009	.005	.0095	.0084	.0078
36	.005	.0075	.004	.009	.0076	.0070
37	.00445	.0065	....	.0085	.0068	.0066
38	.003965	.00575	....	.008	.006	.0063
39	.003531	.005	....	.0075	.0052	.....
40	.003144	.0045	....	.007	.0048	.....

EQUIVALENTS OF ELECTRICAL UNITS

(Hering)

1 kilowatt = 1,000 watts.
1 kilowatt = 1.34 h. p.
1 kilowatt = 44,257 foot-pounds per minute.
1 kilowatt = 56.87 B. t. u. per minute.
1 horse power = 746 watts.
1 horse power = 33,000 foot-pounds per minute.
1 horse power = 42.41 B. t. u. per minute.
1 B. t. u. (British Therman Unit) = 778 foot-pounds.
1 B. t. u. = 0.2930 watt-hr.

TO FIND AMPERES PER PHASE

Three-Phase Circuits

	POWER FACTOR			
VOLTS	100%	90%	80%	70%
110	Kw × 5.256	5.84	6.57	7.51
220	Kw × 2.628	2.92	3.28	3.75
370	Kw × 1.562	1.735	1.952	2.231
380	Kw × 1.521	1.690	1.900	2.170
390	Kw × 1.482	1.646	1.852	2.117
440	Kw × 1.314	1.460	1.640	1.877
550	Kw × 1.050	1.166	1.312	1.500
1100	Kw × .5256	.584	.657	.751
2200	Kw × .2628	.292	.328	.375
2400	Kw × .2400	.266	.3000	.342
3300	Kw × .1750	.1944	.2187	.250
6600	Kw × .0875	.0972	.1093	.125
10000	Kw × .0578	.0640	.0722	.0825
13200	Kw × .0438	.0486	.0546	.0625
16500	Kw × .0350	.0388	.0437	.0500
22000	Kw × .0263	.0292	.0328	.0375
33000	Kw × .0175	.0194	.0219	.0250

Two-Phase Circuits

110	Kw × 4.54	5.04	5.67	6.48
220	Kw × 2.27	2.52	2.83	3.24
440	Kw × 1.13	1.26	1.41	1.62
1100	Kw × .454	.504	.567	.648
2200	Kw × .227	.252	.283	.324

Single-Phase Circuits

110	Kw × 9.09	10.01	11.36	12.98
220	Kw × 4.54	5.05	5.68	6.49
440	Kw × 2.27	2.52	2.84	3.24
1100	Kw × .909	1.01	1.136	1.298
2200	Kw × .454	.505	.568	.649

CURRENT PER PHASE IN VARIOUS SYSTEMS

$$I = \frac{W}{E \times P.F.} \text{ for single-phase circuit.}$$

$$I = 0.50 \times \frac{W}{E \times P.F.} \text{ for two-phase circuit.}$$

$$I = 0.58 \times \frac{W}{E \times P.F.} \text{ for three-phase circuit.}$$

I = Current in line in amperes; W = energy delivered in watts; E = potential between mains in volts; P.F. = power factor. When power factor cannot be accurately determined it may be assumed as follows: Lighting load with no motors, 0.95; lighting load and motors, 0.85; motors only, 0.80.

TABLE OF SPECIFIC RESISTANCE

(Foster)

SUBSTANCE	SPECIFIC RESISTANCE IN MICROHMS PER CUBIC INCH	RELATIVE CONDUCTANCE
Copper (annealed)	1.570	100
Copper (hard)	1,603	98.1
Silver (annealed)	1,492	105
Silver (hard)	1,620	98
Gold	2,077	76
Aluminum (annealed)	2,889	54
Platinum	8,982	17
Iron (pure)	9,628	16
Iron (telegraph wire)	15.	10
Lead	19.63	8,3
Mercury	94.34	1.6

COMPARATIVE RESISTANCE OF VARIOUS METALS

Copper	1	Soft Steel	8	30% Ger. Silver	28
Aluminum	1.5	No. 15 Alloy	12	"Advance"	28
No. 5 Alloy	2	"Ferro-Nickel"	17	"Climax"	50
Platinum	6	18% Ger. Silver	19	"Nichrome"	60
Norway Iron	7	"Yankee Silver"	20	"Nichrome II"	66
Pure Nickel	7	"Therlo"	27		

COLORS OF SOURCES OF LIGHT

SOURCE	COLOR
High sun	White
Electric arc, short	White
Electric arc, long	Blue-white to violet
Nernst glower	White to yellowish white
Tungsten filament	Nearly white
Carbon filament	Yellowish white
Mercury arc	Blue-green

The foregoing comparative figures giving the brilliancy of various illuminants show the tremendous advantage of the electric arc for projecting purposes. In fact there is no substitute for the electric arc at the present time, although calcium light can be used in case of necessity for traveling exhibits.

BRIGHTNESS OF VARIOUS ILLUMINANTS

SOURCE	C.P. PER SQ. IN.	NOTES
Sun (in zenith)	600,000	Necessarily rough estimate
Electric arc	10,000 to 100,000	Reaching often 200,000 in the crater of a very powerful arc
Calcium light	5,000	
Nernst glower	1,000	
Incandescent lamps	200 to 500	Depending on efficiency, some metallic filament lamps run above 1,000

The above table is of great interest because it shows the value of maintaining an electric arc short when used for projection. Only by maintaining the arc short is it possible to secure a white light. Whenever the arc is maintained long, the light becomes blue-white to violet and is much inferior for projection purposes. As a matter of fact, the only way of getting an illumination which is equal in quality to the high sun is obtained by an electric arc between pure carbon points maintained short.

TABLE OF REFLECTION COEFFICIENTS

Material	Coefficient	Material	Coefficient
Polished silver	92 to 93	Yellow cardboard	30
Mirror silvered on back	82 to 88	Light blue cardboard	25
White blotting paper	82	Brown cardboard	20
White cartridge paper	80	Yellow painted wall, dirty	20
Polished brass	70 to 75	Emerald green paper	18
Mirror backed with Amalgam	70	Dark brown paper	13
Ordinary foolscap paper	70	Vermilion paper	12
Chrome-yellow paper	62	Bluish green paper	12
Orange paper	50	Cobalt blue paper	12
Yellow wall paper	40	Black paper	5
Yellow-painted wall	40	Ultramarine blue paper	3.5
Light pink paper	36	Black velvet	.4

The light reflected from a surface in per cent. of the total light falling upon that surface is called the reflection coefficient.

A careful perusal of the figures in the above table brings out the important point that a surface similar to a common white blotting paper possesses almost as much reflective power as a mirror silvered on the back. These figures have been carefully prepared by a special committee of the National Electric Light Association and may be absolutely relied upon. The figures would indicate that a pure white screen, by that I mean a screen with a surface which is not glossy, makes about the best arrangement for picture projection. A plastered wall having a dull white surface, or possibly if coated with some of the special compounds tinting toward a grayish blue will make a splendid screen upon which to project motion pictures. The pictures on such a screen stand out in better relief than if a polished or metallic surface is used, and besides the flicker is cut down to a minimum.

This table is also of great benefit to the exhibitor who is arranging for the ornamentation of the interior of a picture theater, because it is a positive guide as to the various reflective powers of the different color schemes. You will, of course, keep in mind that for the decoration, those colors which have the lowest reflection coefficient should be selected, and it is interesting to know that the browns and greens are of exceptional value in this respect.

ENERGY RADIATION

When a body is heated above the surroundings, it radiates energy; at first in the form of heat, and later, when certain wave lengths are reached, a portion of the radiant energy is in the form of light. Electric energy is easily applied to bodies whose temperature it is desired to raise to a point where they become incandescent and give off light. In an electric lamp the electric energy is completely transformed into heat, a large portion of which is given off as radiant energy. Part of the radiations are visible and constitute light; however, a comparatively small proportion of the total energy is given off in this form. The maximum radiation energy approaches visible radiation more and more as the temperature of the radiating body is increased. It is by increasing the temperature of the filament that its specific consumption in watts per candle power is decreased, and this is why high efficiency lamps have shorter lives than the less efficient lamps of the same kind. The maximum possible efficiency would be reached at a temperature of about 6800 degrees centigrade, which no known solid will endure. As a matter of fact, the usual temperature at which the filament of an incandescent lamp is worked lies between 1550 and 1600 degrees centigrade.

ELECTRIC SIGNS

There are many kinds of electric signs; some flash out and in and others seem to be written with an invisible hand. Occasionally the inscriptions appear sentence by sentence or word by word. There are signs in the form of emblems, trademarks, flags, eagles, etc., studded with sockets; live borders for signs, such as crawling serpents, jumping grasshoppers or rabbits, but the most popular form of electric sign gives a steady illumination with white or colored lamps; the letters may be interchangeable so as to alter the reading occasionally if desired. An electric sign should be considered as an advertising investment, and if the impression it makes is not a good one, the money invested in it is worse than thrown away. It should lend a distinguishing air of quality to a theater and it is this element which gives it its greatest value. While a sign will designate a place of business, and perhaps the nature of that business, a large part of its value lies in the impression it makes. Hence only the best and most permanent types of sign should be adopted, no matter how small they must be, to meet the price the customer can afford to pay for one.

Some of the essentials of a good sign are that it should be made of the very best materials, carefully put together and simple in construction, so that it may be very durable. It must be waterproof and have a surface preferably of enameled metal that will not fade or lose its color. Mechanical arrangements for its suspension must be such that it is rigidly and safely supported, not only actually, but in appearance.

Turning from such generalities as the preceding with the assumption that electric signs are of great value as advertising mediums, it will be well to consider more in detail what the actual cost of electric advertising will be.

The reading on a sign should be made as brief as possible and large letters should be employed, spaced well apart. Raised letters are more effective than flush letters, standing out much more prominently both day and night. When signs are placed flat against a building, grooved letters should be used, as they show more plainly and need fewer lamps.

The price of an electric sign naturally depends upon the number and size of the letters required and the number of lamps necessary to illuminate them. The price for a single letter illuminated by the minimum number of lamps required to give a good effect, ranges, on an average, from $6 to $12 a year according to the height of the letters. The following table will enable the reader to make a fairly accurate calculation as to the price for which a satisfactory sign can be obtained:

COST OF ELECTRIC SIGNS

Of standard block style letters, made of metal on a full metal background Japan-enameled.

HEIGHT OF LETTERS IN INCHES	AVERAGE NUMBER OF LAMPS PER LETTER		PRICE PER LETTER DOLLARS
	RAISED	GROOVED	
10	6	4	6.20
12	8	6	6.80
14	8	6	7.00
16	10	8	7.60
18	10	8	7.90
20	10	8	8.20
24	12	10	9.40
30	14	10	10.70
36	16	12	12.80

Signs with flush letters would be about 20% less expensive, while any special style of letter, such as the old English or pointed block would be from 2.5% to 20% higher. The prices indicated in the table do not, of course, include extras such as non-electric lettering or special ornamentation. Neither do they include the cost of material for hanging the sign, or of wiring for writing or spelling flashers. But even then these figures work out at a great deal less than the sum that many people imagine must be spent for an electric sign. The same thing also applies to the cost of operation—it is far less formidable than is generally supposed. For example, if a sign contains 4 c.p. lamps, it takes 50 lamps to make up a kilowatt of capacity and if it contains 2 c.p. lamps, it takes approximately 80 to make up a kilowatt. Multiply its capacity in kilowatts by the number of hours during which the sign will burn each night and the nightly consumption of energy in kilowatt-hours is thus obtained. Knowing the rate charged for energy, it is easy to multiply the number of kilowatt-hours by the rate, and thus get the nightly cost of signs containing various numbers of lamps.

COST OF OPERATING AN ELECTRIC SIGN PER HOUR

At the rate of 10 cents per kilowatt-hour, using 4 or 2 c.p. lamps.

Average efficiency carbon filament lamps.

NUMBER OF LAMPS IN SIGN	4 C.P. LAMPS COST PER HOUR CENTS	2 C.P. LAMPS COST PER HOUR CENTS
25	5	3
50	10	6
75	15	9
100	20	12
150	30	18
200	40	24

Note—If Tungsten or Mazda lamps are used, current cost is 50 to 70% lower. Average number of hours burning per month, 75 to 150.

If the cost of illuminating a sign is compared with the cost of advertising in a local paper, the comparison will be found to be in favor of the sign, especially as it points out the exact position of the theater and attracts people to it.

COMPARISON OF LIGHT

Given for same cost per 1,000 hours—100-Watt Tungsten and 100-Watt carbon lamps; and saving for equal light.

	TUNGSTEN 1-100 WATT 1.20 W.P.C.	CARBON 1-100 WATT 2.97 W.P.C.	CARBON 2.48-100 WATT 2.97 W.P.C.
Candle power	83.3	33.6	83.3
Average cost of lamps	1.04	.24	.595
Average life of lamps	1,000	600	600
Renewal cost per 1,000 hours	1.04	.40	.0917
Power consumed per 100 hours k.w.h.	100.	100.	248.
Cost of power at 5 cts.	5.00	5.00	12.40
Cost of power at 10 cts.	10.00	10.00	24.80
Cost of renewals and power at 5 cts.	6.04	5.40	13.39
Cost of renewals and power at 10 cts.	11.04	10.40	25.79
Comparison of light for same cost	100%	42.8%	42.8%
% saving for equal light — 5 cts.	55	......	0.0
% saving for equal light — 10 cts.	57	......	0.0

This makes an average saving of 56 per cent. in the cost for lamp renewals and power, in addition to which there is a saving effected in the cost for wiring by the reduction of the number of outlets, the quantity of material, and the reduction of the load.

FANS AND BLOWERS

To procure fresh air and to keep it in circulation is a problem of particular interest to those who are compelled to be either temporarily or permanently indoors. In summer, especially, and in inland and low sections of the country, arrangements for good ventilation become a matter of business necessity to render a theater, store, shop, or factory even habitable during the hot months, and in the winter it is an equally important matter where a large number of people congregate.

For such ventilation it is not only necessary to draw in pure air, but to remove the vitiated air, and to continue this process indefinitely. For many industrial purposes, however, the desired object is to remove moist air from the rooms in which lumber, cloth, paper, tobacco, or other articles of merchandise are being dried, to exhaust from the rooms those noxious gases or fumes which attend certain processes of manufacture or to cause a circulation of air over heated or cooled pipe coils for maintaining equable temperature in assembly rooms or apartments. Though this was not formerly an easy matter to accomplish, apparatus is now obtainable which will readily produce the required results.

A ventilating fan of the propeller type is usually fixed in a circular aperture in the wall and can be arranged as desired—either to draw in fresh air or expel bad air. An exhaust fan should be placed so that it discharges the air in the same direction as the prevailing wind, in order to avoid having to contend with wind pressure. The number and location of air inlets and probable effects of prevailing air currents should also be considered carefully in determining the place for the fan. Under ideal conditions the room to be ventilated should have only one inlet for air which should be at the opposite end of the room from the exhaust fan. The size of the fan to be installed, of course, depends upon local conditions, but roughly speaking, the 18 in. size will be found sufficient to provide fresh air for 25 to 30 persons. This allows for the provision of 2,000 cubic feet of air per hour for each occupant of the room.

APPROXIMATE PRICES FOR FANS

Alternating Variable Speed Exhaust Fans

110 OR 220 VOLTS AS SPECIFIED

	H.P.	Watts per hour	At 10c rate per hour cost of operation at full speed	Size	Cycle	Revolutions per minute	Cubic feet of air per minute	Price
Non-reversible without speed regulator	1-10	45	½c.	12	60	1500	750	$16.00
	⅛	85	¾c.	16	60	1500	1,300	20.00
With speed regulator non-reversible	1-6	150	1½c.	18	60	80 to 800	2,500	72.00
Reversible with speed regulator	½	400	4 c.	24	60	80 to 750	6,000	100.00
Reversible with speed regulator	1	800	8 c.	30	60	80 to 700	12,800	165.00
Reversible with speed regulator (for 220 volts only)...	1½	1200	12 c.	36	60	80 to 650	17,300	225.00

Direct Current Exhaust Fans

For direct-current circuits, 100 to 230 volts, the ventilating exhaust fans possess all the advantages above described for the alternating fans, except that they are not made reversible.

	H.P.	Watts per hour	At 10c rate per hour, cost of operation at full speed	Size	Revolutions per minute	Cubic feet of air per minute	Price
Without speed regulator ..	1-10	45	½c.	12	1500	1,000	$16.00
	⅛	85	¾c.	16	1200	1,600	20.00
With speed regulator	¼	200	2 c.	18	1000	4,060	75.00
With speed regulator	½	400	4 c.	24	850	7,620	100.00
With speed regulator	¾	600	6 c.	30	640	12,400	125.00
With speed regulator	1¼	1000	10 c.	36	525	18,000	165.00

The foregoing data of exhaust fans for alternating and direct current is intended to be used as a guide. The cost of operating may vary slightly for various makes of fans and the cost prices given are only approximate, also subject to variation depending upon the make and style of fan wanted.

WEIGHTS AND MEASURES

Troy Weight

24 grains	= 1 pwt.	12 ounces	= 1 pound
20 pwt.	= 1 ounce		

Used for weighing gold, silver and jewels.

Apothecaries' Weight

20 grains	= 1 scruple	8 drams	= 1 ounce
3 scruples	= 1 dram	12 ounces	= 1 pound

The ounce and pound in this are the same as in Troy weight.

Avoirdupois Weight

27⅓ grains	= 1 dram	4 quarters	= 1 cwt.
16 drams	= 1 ounce	2,000 lbs.	= 1 short ton
16 ounces	= 1 pound	2,240 lbs.	= 1 long ton
25 pounds	= 1 quarter		

Dry Measure

2 pints	= 1 quart	4 pecks	= 1 bushel
8 quarts	= 1 peck	36 bushels	= 1 chaldron

Liquid Measure

4 gills	= 1 pint	31½ gallons	= 1 barrel
2 pints	= 1 quart	2 barrels	= 1 hogshead
4 quarts	= 1 gallon		

Long Measure

12 inches	= 1 foot	40 rods	= 1 furlong
3 feet	= 1 yard	8 furlongs	= 1 sta. mile
5½ yards	= 1 rod	3 miles	= 1 league

Square Measure

144 sq. in.	= 1 sq. ft.	40 sq. rods	= 1 rood
9 sq. ft.	= 1 sq. yd.	4 roods	= 1 acre
30¼ sq. yds.	= 1 sq. rod	640 acres	= 1 sq. mile

Surveyors' Measure

7.92 inches	=	1 link
25 links	=	1 rod
4 rods	=	1 chain
10 sq. chains or 160 sq. rds.	=	1 acre
640 acres	=	1 sq. mile
36 sq. miles (6 miles sq.)	=	1 township

Cubic Measure

1,728 cubic in.	=	1 cu. ft.
27 cu. ft.	=	1 cu. yd.
128 cu. ft.	=	1 cord (wood)
40 cu. ft.	=	1 ton (shpg)
2,150.42 cubic inches	=	1 standard bushel
231 cubic inches	=	1 U. S. standard gallon
1 cu. ft.	=	about 4/5 of a bushel

Metric Equivalents—Linear Measure

1 centimeter	=	0.3937	in.
1 in.	=	2.54	centimeters
1 decimeter (3.937 in.)	=	0.328	ft.
1 ft.	=	3.048	decimeters
1 meter (39.37 in.)	=	1.0936	yards
1 yd.	=	0.9144	meter
1 dekameter	=	1.9884	rds.
1 kilometer	=	0.62137	m.
1 rd.	=	0.5029	dekameter
1 m.	=	1.6093	kilometers

Square Measure

1 sq. centimeter	=	0.1550	sq. in.
1 sq. decimeter	=	0.1076	sq. ft.
1 sq. meter	=	1.196	sq. yd.
1 are	=	3.954	sq. rds.
1 hectare	=	2.47	acres
1 sq. kilometer	=	0.386	sq. m.
1 sq. in.	=	6.452	sq. centimeters
1 sq. ft.	=	9.2903	sq. decimeters
1 sq. yd.	=	0.8361	sq. meter
1 sq. rd.	=	0.2529	are
1 acre	=	0.4047	hectare
1 sq. m.	=	2.59	sq. kilometers

Weights

1 gram	=	0.03527	ounce
1 kilogram	=	2.2046	lbs.
1 metric ton	=	1.1023	English tons
1 ounce	=	28.35	grams
1 lb.	=	0.4536	kilogram
1 English ton	=	0.9072	metric ton

Approximate Metric Equivalents

1 decimeter	=	4 in.
1 meter	=	1.1 yds.
1 kilometer	=	5/8 of a mile
1 hectare	=	2½ acres
1 stere, or cu. meter	=	¼ of a cord
1 liter	=	1.06 qts. liquid, 0.9 qt. dry
1 hektoliter	=	2½ bus.
1 kilogram	=	2⅕ lbs.
1 metric ton	=	2,200 lbs.

STRENGTH OF MATERIALS

MATERIALS	TENSILE STRENGTH POUNDS PER SQ. IN.	COMPRESSIVE STRENGTH POUNDS PER SQ. IN.
Alum. Bronze, 10% Alum...	85,000	
Alum. Bronze, 1¼% Alum..	28,000	
Brass, Cast.................	22,000	10,300
Brass, Wire.................	49,000	
Bronze or Gun Metal.......	36,000	
Copper, Cast	19,000	
Sheet	30,000	
Wire	49,000– 67,000	
Iron, Cast	13,400– 29,000	82,000–145,000
Wrought	46,000– 54,000	36,000– 40,000
Lead, Sheet................	3,300	
Steel, Cast	61,000–120,000	
Rivet	50,000– 60,000	
Axle	75,000– 90,000	
Wire	200,000–240,000	
Boiler	55,000– 65,000	
Soft Open Hearth...	52,000– 62,000	
Brickwork, Ordinary	....	300– 500
Cement	....	450– 1,000
Cement, Portland, 1 to 1, Neat	550– 650	5,000– 10,000
Granite and Limestone.....	....	8,000– 25,000
Sandstones	....	6,000– 10,000
Glass (Common)..........	4,800–	20,000– 40,000
Ash (Wood)..............	11,000– 17,000	4,400– 9,400
Hemp Ropes...............	12,000– 16,000	
Hickory	12,800– 18,000	8,900
Oak (White).............	10,000– 20,000	4,600– 9,500
Pine (Yellow)............	12,000– 19,200	5,400– 9,500
Chestnut	10,500	5,350– 5,600
Locust	20,000– 25,000	9,100– 11,700
Spruce	10,000– 19,500	5,000– 7,800

CENTIGRADE AND FAHRENHEIT SCALES

CENTIGRADE	FAHRENHEIT	CENTIGRADE	FAHRENHEIT
0	32	50	122
5	41	55	131
10	50	60	140
15	59	65	149
20	68	70	158
25	77	75	167
30	86	80	176
35	95	85	185
38	100.4	90	194
40	104	95	203
42	107.6	100	212
45	113	...	...

Temp. C = 5/9 (Temp. F — 32)
Temp. F = 9/5 (Temp. C + 32)

EFFECT OF HEAT ON MATERIALS

	MELTING POINT FAHRENHEIT
Mercury	—39
Tin	442
Bismuth	507
Lead	617
Zinc	773
Antimony	1,150
Aluminum	1,157
Bronze	1,692
Silver	1,873
Copper	1,996
Gold	2,016
Cast Iron, Gray	2,786
Steel	2,372 to 2,552

HIGH TEMPERATURES JUDGED BY COLOR

(Kent)

v The temperature of a body can be approximately judged by the experienced eye unaided, and M. Pouillet has constructed a table which has been generally accepted, giving the colors and their corresponding temperatures as below:

COLOR	DEG. C	DEG. F
Incipient red heat	525	977
Dull red heat	700	1,292
Incipient cherry-red heat	800	1,472
Cherry-red heat	900	1,652
Clear cherry-red heat	1,000	1,832
Deep orange heat	1,100	2,021
Clear orange heat	1,200	2,192
White heat	1,300	2,372
Bright white heat	1,400	2,552
Dazzling white heat	1,500 to 1,600	2,732 to 2,912

HEAT UNITS

(Foster)

1 Kw-hr. =

- 1,000 watt-hr.
- 1.34 h.p.-hr.
- 2,654,200 ft.-lb.
- 3,600,000 joules.
- 3,412 heat-units.
- 367,000 kg-m.
- .235 lb. carbon oxidized with perfect efficiency.
- 3.53 lb. water evap. from and at 212° F.
- 22.75 lb. of water raised from 60° to 212° F.

1 h.p.-hr =

- .746 kw-hr.
- 1,980,000 ft.-lb.
- 2,545 heat-units.
- 273,740 kg-m.
- .175 lb. carbon oxidized with perfect efficiency.
- 2.64 water evaporated from and at 212° F.
- 17.0 lb. water raised from 62° F. to 212° F.

1 lb. carbon oxidized with perfect efficiency =

- 14.544 heat units.
- 1.11 lb. anthracite coal oxidized.
- 2.5 lbs. dry wood oxidized.
- 21 cu. ft. illuminating gas.
- 4.26 kw-hr.
- 5.71 h.p.-hr.
- 11,315,000 ft.-lb.
- 15 lb. of water evaporated from and at 212° F.

1 lb. water evaporated from and at 212° F. =

- .283 kw.-hr.
- .379 h.p.-hr.
- 965.7 heat units.
- 103,900 kg-m.
- 1,019,000 joules.
- 751,300 ft.-lb.
- .0664 of carbon oxidized.

HEATING VALUES FOR LIQUID FUELS

(Gill)

	SP. GR.	FLASH DEG. F.	FIRE DEG. F.	HEAT VALUE B. T. U. PER LB.	SP. HEAT
76 deg. Gasoline..	76.5	...	...	18,080	0.55
62 deg. Naphtha..	61.0	...	...	17,860	0.50
135 deg. Fire T Kerosene	48.0	125	135	17,810	0.50
150 deg. Fire T Kerosene	48.0	134	150	18,290	0.49
Beaumont Crude..	0.924	180	200	19.060	
California	0.966	230	311	18,667	
Cal. and Texas....	0.966	270	280	19,215	
Pennsylvania	0.886			19,224	
Wyoming	0.996			19,668	
Residuum, Va. ...	L. 860			19,200	
Residuum, Rus'n..	0.884			19,926	

WEIGHT OF MATERIALS AND LIQUIDS

	WEIGHT OF ONE CUBIC FOOT POUNDS	SPECIFIC GRAVITY WATER = 1
Platinum	1,342	21.522
Gold	1,200	19.245
Mercury, fluid	849	13.596
Lead, wire	704	11.282
Silver	655	10.505
Bismuth	617	9.90
Copper, sheet	549	8.805
Copper, wire	554	8.880
Bronze	544	8.73
Nickel, cast	516	8.28
Brass, cast	505	8.10
Brass, wire	533	8.548
Steel	489.6	7.852
Iron, wrought	480	7.698
Iron, cast	450	7.217
Tin	462	7.409
Zinc, sheet	449	7.20
Antimony	418	6.71
Aluminum, wrought	167	2.67
Aluminum, cast	160	2.56
Magnesium	108.5	1.74
Sulphuric Acid	114.9	1.84
Nitric Acid	76.2	1.22
Pure Water	62.425	1.000
Oil, linseed	58.7	0.94
Oil, turpentine	54.3	0.87
Petroleum	54.9	0.88
Naphtha	53.1	0.85
Ether, sulphuric	44.9	0.72
Benzine	53.1	0.85

DECIMALS OF AN INCH FOR EACH ONE SIXTY-FOURTH

32DS	64THS	DECIMAL	FRACTION	32DS	64THS	DECIMAL	FRACTION
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1/16	18	36	.5625	9/16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	⅛	20	40	.625	⅝
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3/16	22	44	.6875	11/16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	¼	24	48	.75	¾
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5/16	26	52	.8125	13/16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	⅜	28	56	.875	⅞
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7/16	30	60	.9375	15/16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	½	32	64	1.	1

TABLE FOR FILM PROJECTION

Aperture Opening, 11/16 x 15/16

Equiv. Focus in inches	Distance from Film to Screen												
	15 ft.	20 ft.	25 ft.	30 ft.	35 ft.	40 ft.	45 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.
2	5.1	6 8	8.5	10.3	12.0	13.7	15.4	17.1	20.6	24.0	27.5	30.8	34.3
	7.0	9.3	11.6	14.0	16.4	18.7	21.1	23.4	29.4	32.7	37.4	42.1	46.8
2⅛	4.8	6.4	8.0	9.6	11.3	12.9	14.5	16.1	19.4	22.6	25.8	28.9	32.3
	6.5	8.7	11.0	13.2	15.4	17.6	19.8	22.0	26.4	30.8	35.2	39.3	44.0
2¼	4.5	6.1	7.6	9.1	10.6	12.2	13.7	15.2	18.3	21.3	24.4	27.2	30.5
	6.2	8.3	10.3	12.4	14.5	16.6	18.7	20.8	24.9	29.1	33.2	37.2	41.6
2½	4.1	5.4	6.8	8.2	9.6	10.9	12.3	13.7	16.4	19.2	22.0	24.5	27.4
	5.6	7.4	9.3	11.2	13.1	14.9	16.8	18.7	22.4	26.2	29.9	33.4	37.4
2¾	3.7	4.9	6.2	7.4	8.7	9.9	11.2	12.5	15.0	17.4	20.0	22.3	24.9
	5.0	6.7	8.4	10.2	11.9	13.6	15.3	17.0	20.4	23.8	27.2	30.4	34.0
3	3.4	4.5	5.7	6.8	8.0	9.1	10.3	11.4	13.7	16.0	18.3	20.4	22.9
	4.6	6.2	7.7	9.3	10.9	12.4	14.0	15.6	18.7	21.8	24.9	27.8	31.2
3¼	3.1	4.2	5.2	6.3	7.3	8.4	9.5	10.5	12.6	14.8	16.9	18.9	21.1
	4.3	5.7	7.1	8.6	10.0	11.5	12.9	14.4	17.2	20.1	23.0	25.7	28.8
3½	2.9	3.9	4.9	5.8	6.8	7.8	8.8	9.8	11.7	13.7	15.7	17.6	19.6
	4.1	5.3	6.6	8.0	9.3	10.6	12.0	13.3	16.0	18.7	21.4	24.0	26.7
3¾	2.7	3.6	4.5	5.4	6.4	7.3	8.2	9.1	11.0	12.8	14.6	16.4	18.3
	4.0	4.9	6.2	7.4	8.7	9.9	11.2	12.4	14.9	17.4	19.9	22.4	24.9
4	2.6	3.4	4.2	5.1	6.0	6.8	7.7	8.5	10.3	12.0	13.7	15.4	17.1
	3.8	4.6	5.8	7.0	8.1	9.3	10.5	11.6	14.0	16.3	18.7	21.0	23.4
4¼	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	9.6	11.3	12.9	14.5	16.1
	3.6	4.3	5.4	6.5	7.6	8.7	9.8	11.2	13.2	15.4	17.6	19.8	22.0
4½	2.2	3.0	3.8	4.5	5.3	6.2	6.8	7.7	9.1	10.6	12.2	13.7	15.4
	3.4	4.1	5.1	6.2	7.2	8.4	9.3	10.5	12.4	14.5	16.6	18.7	21.0
4¾	2.0	2.8	3.6	4.3	5.0	5.7	6.5	7.2	8.6	10.1	11.5	13.0	14.4
	3.2	3.9	4.9	5.8	6.8	7.8	9.2	9.8	11.8	13.7	15.7	17.7	19.7
5	1.9	2.6	3.4	4.1	4.8	5.4	6.1	6.8	8.2	9.2	10.9	12.3	13.7
	3.1	3.7	4.6	5.5	6.5	7.4	8.4	9.3	11.2	13.0	14.9	16.8	18.7
5¼	1.8	2.5	3.2	3.9	4.5	5.2	5.8	6.5	7.8	9.1	10.4	11.7	13.0
	2.9	3.5	4.4	5.3	6.2	6.9	8.0	8.8	10.6	12.4	14.2	16.0	17.8
5½	1.7	2.4	3.1	3.7	4.3	4.9	5.6	6.2	7.4	8.7	9.9	11.2	12.4
	2.8	3.3	4.2	5.0	5.9	6.7	7.6	8.4	10.2	11.9	13.6	15.3	17.0
5¾	1.6	2.3	2.9	3.5	4.1	4.7	5.3	5.9	7.1	8.3	9.5	10.7	11.9
	2.7	3.2	4.0	4.8	5.6	6.4	7.3	8.1	9.7	11.3	13.0	14.6	16.2
6	1.5	2.2	2.8	3.4	4.0	4.5	5.1	5.7	6.8	8.0	9.1	10.3	11.4
	2.6	3.1	3.8	4.6	5.4	6.2	7.0	7.7	9.3	10.9	12.4	14.0	15.6
6½							4.7	5.2	6.3	7.3	8.4	9.6	10.6
							6.4	7.1	8.6	10.0	11.4	13.0	14.5
							4.4	4.9	5.8	6.8	7.8	8.8	9.8
							6.0	6.6	8.0	9.3	10.6	12.0	13.3
7½								4.5	5.4	6.4	7.3	8.2	9.1
								6.2	7.4	8.7	10.0	11.2	12.3
8									5.1	6.0	6.8	7.7	8.5
									7.0	8.1	9.3	10.5	11.6

Example—With a lens of 5½-inch focus at a distance of 35 ft., the screen image will be 4.3 x 5.9; at 40 ft., 5.6 x 7.6, etc.

TABLE FOR STEREOPTICON PROJECTION

2¾ x 3 in. Mat Opening

Equiv. Focus in inches	Distance from Slide to Screen 15 ft.	20 ft.	25 ft.	30 ft.	35 ft.	40 ft.	45 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft
8		6.6	8.4	10.1	11.8	13.5	15.2	17.0	20.4				
		7.3	9.1	11.0	12.9	14.8	16.6	18.5	22.3				
8½		6.2	7.9	9.5	11.1	12.7	14.3	16.0	19.2				
		6.8	8.6	10.3	12.1	13.9	15.6	17.4	20.9				
9		5.9	7.4	8.9	10.5	12.0	13.5	15.1	18.1	21.1			
		6.4	8.1	9.8	11.4	13.1	14.8	16.4	19.8	23.1			
9½		5.6	7.0	8.5	9.9	11.4	12.8	14.2	17.1	20.0			
		6.1	7.6	9.2	10.8	12.4	14.0	15.5	18.7	21.9			
10		5.3	6.6	8.0	9.4	10.8	12.2	13.5	16.3	19.0	21.8		
		5.8	7.3	8.8	10.3	11.8	13.3	14.8	17.8	20.8	23.8		
12			5.5	6.6	7.8	8.9	10.1	11.2	13.5	15.8	18.1	20.4	
			6.0	7.3	8.5	9.8	11.0	12.3	14.8	17.3	19.8	22.3	
14				5.6	6.6	7.6	8.6	9.6	11.6	13.5	15.5	17.5	19.4
				6.2	7.3	8.3	9.4	10.5	12.6	14.8	16.9	19.0	21.2
15					6.2	7.1	8.0	8.9	10.8	12.6	14.4	16.3	18.1
					6.7	7.7	8.7	9.7	11.7	13.7	15.7	17.7	19.7
16					5.8	6.6	7.5	8.4	10.1	11.8	13.5	15.2	17.0
					6.3	7.3	8.2	9.1	11.0	12.9	14.8	16.6	18.5
17					5.4	6.2	7.0	7.8	9.5	11.1	12.7	14.3	15.9
					5.9	6.8	7.7	8.6	10.3	12.1	13.9	15.7	17.5
18					5.1	5.9	6.6	7.4	8.9	10.5	12.0	13.5	15.1
					5.6	6.4	7.3	8.1	9.8	11.4	13.1	14.8	16.4
20						5.3	6.0	6.6	8.0	9.4	10.8	12.2	13.5
						5.8	6.5	7.3	8.8	10.3	11.8	13.3	14.8
22							5.4	6.0	7.3	8.5	9.8	11.0	12.3
							5.9	6.6	7.9	9.3	10.7	12.0	13.4
24								5.5	6.6	7.8	8.9	10.1	11.2
								6.0	7.3	8.5	9.8	11.0	12.3
26								5.0	6.1	7.2	8.2	9.3	10.4
								5.5	6.7	7.9	9.0	10.1	11.2
28								5.0	5.7	6.3	7.0	7.6	8.2
								5.5	6.2	6.9	7.7	8.4	9.1

CALCIUM LIGHT

This light is known by the names of Oxy-Hydrogen, Calcium, or Lime light, and is the most practical and satisfactory method of providing an intense light for magic lanterns and stereopticon illumination. Calcium light is produced by an incandescent surface on a piece of hard, unslaked lime, and is created by the combustion of a combination of oxygen and hydrogen gases. The oxygen and hydrogen gases are each kept in separate tanks or receptacles under heavy pressure, and are connected by rubber tubes to the jet where they combine.

A cylinder of lime (about three-fourths of an inch in diameter) is placed in a vertical position in the three-pronged circular fork, near the opening of the jet, and the combustion of the combined gases on its surface creates a small disk of light of dazzling whiteness. The brilliancy of the rays proceeding from this light is so intense that they will illuminate the projected views over an area of 25 or 30 feet square, if necessary. Owing to its extreme intensity it has great penetration, and is, therefore, the

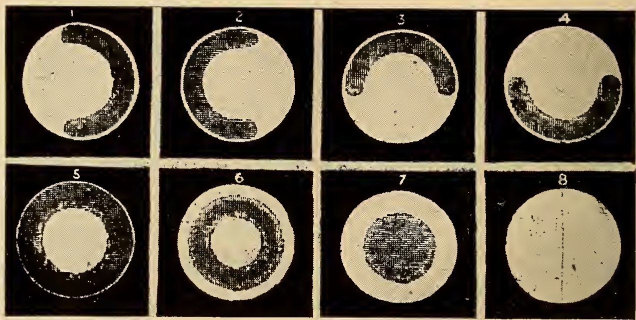


Fig. 126

most desirable illumination in halls of moderate size, and is almost indispensable for the largest churches, opera houses and theaters. No other light has ever been produced which will equal it, everything considered, for magic lantern or stereopticon projection.

DIRECTIONS FOR THE USE OF CALCIUM LIGHT

Some operators use rubber bags for the storing of the hydrogen and oxygen gases, while some prefer to get their supply from the city gas companies in steel tanks made for that purpose, but for use in smaller towns and cities, the portable calcium light and gas-making outfit gives the most universal satisfaction. In either case, the receptacles are provided with nipples for attaching the rubber tubes which are used to connect them with the calcium light jets.

The tanks furnished by the city gas companies are painted to designate the kind of gas contained in each. The red tank contains the oxygen while the black tank contains the hydrogen gas.

Slip one end of the rubber tube onto the nipple of the hydrogen gas tank or bag, and connect the other end with the left hand side of the jet. Connect one end of the other rubber tube with the oxygen bag or tank, and the other to the right side of the calcium jet. Now take a piece of lime from the box in which they are packed, and you will no doubt find that it is a little too large to go into the holder. Such being the case, take a knife and shave a little off of the three sides, leaving it just large enough so that the lime will fit snugly into the holder, then adjust it so it sets perfectly upright, and when it is revolved by the holder it will not vary too much from a perfectly upright position.

The jet should now be placed in the lamp house, with the lime about three or four inches from the condensing lenses.

Open the valve of the hydrogen tank, light the gas at the jet and turn on the hydrogen until the flame is from four to six inches high, then turn on a sufficient amount of the oxygen gas to almost consume the hydrogen flame. When the oxygen is turned on it creates a kind of whistling sound and this will continue until the right proportion of oxygen is mixed with the hydrogen. When the right proportion is reached, the light will burn without any noise whatever and almost no flame. If too much oxygen is turned on it will produce a roaring noise, and if the oxygen is allowed to flow too much in excess of its proper proportion, the light will extinguish itself with a sharp snap. Should this occur, it will be necessary to turn off the oxygen and immediately light the hydrogen, or turn both off and start anew. In adjusting the flow of oxygen in proportion to the hydrogen, it is necessary to turn the valves slowly, so as to be able to stop when the right proportion is reached. The surface of the lime should be about one-eighth to one-fourth of an inch from the opening of the jet, to obtain the best results.

ADJUSTMENT OF LIGHT

Successful results in projection depend largely upon the correct adjustment of the lamp, which must throw a brilliantly illuminated circle upon the screen.

After the objective is focused, as will be evidenced by

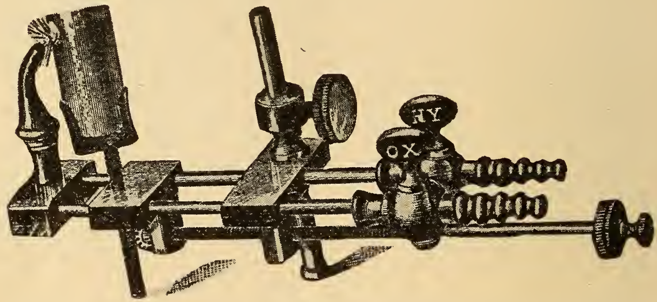


Fig. 127

a sharp clear image on the screen, remove slide and slide-holder, and examine the illuminated circle. If the light is centered and the lamp correctly adjusted this circle will be clear and entirely free from coloration or shadows.

Fig. 127 illustrates the results of defective centering, showing the shadows and stating the causes. These can be speedily remedied and a little practice will soon make one adept in centering the light accurately.

In Figs. 1 and 2 the radiant, i. e., the crater, needs to be properly adjusted laterally, it is too far to the right or left.

In Figs. 3 and 4 it is too high or too low.

In Fig. 5, 6 and 7 it is too near or too far from the condenser.

Fig. 8 shows it to be in correct position, the field being entirely clear.

These instructions hold good for the electric arc as well.

The lime cylinder should be turned as often as every five minutes. Failure to do this is liable to form a pit in the surface of the lime, which may throw a tongue of flame against the condensers, and break them. Usually the light will begin to hiss when the surface is much pitted, and it should be immediately turned. If the opening in the point of the jet is too far away from the lime, it is liable also to cause hissing.

Those who do not care to make their own gas, can get tanks from the large cities. They are supplied by the calcium light companies of this city at $6.25 per pair. A pair of tanks are supposed to last from four to six nights. To those who wish to use calcium light, we would recommend the "Model B" calcium gas-making outfit. The limes are unslacked, and should be kept in air-tight cans when not in use. The proper distance of the lime from the condenser will be found to be about three to three and one-half inches.

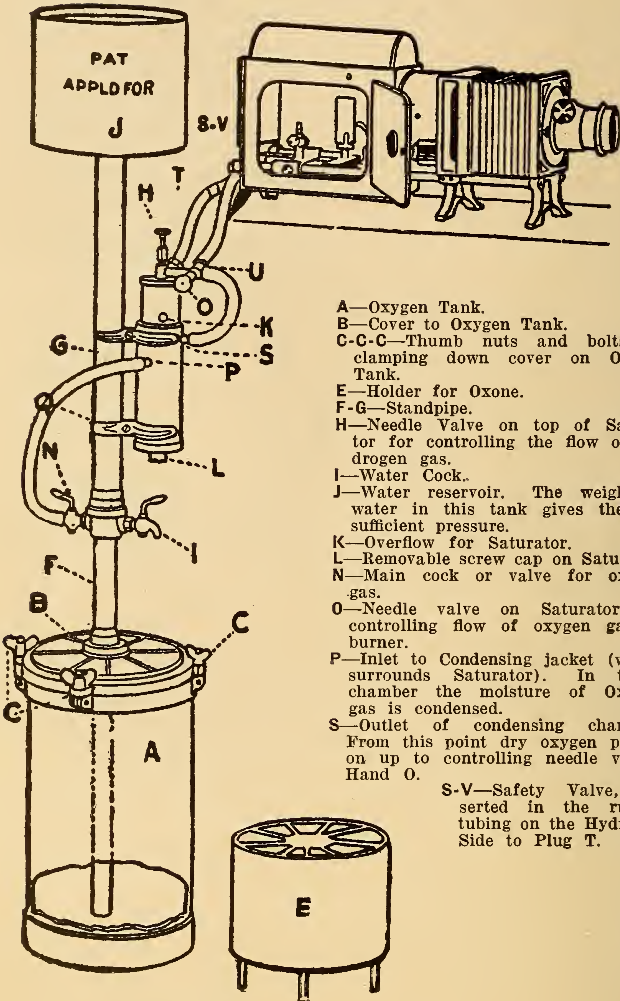
"MODEL B" CALCIUM GAS MAKING OUTFIT WITH DIRECTIONS FOR OPERATING

For convenience in shipping, the outfit has been taken apart, so as to pack it into small space. Take all parts from the case, loosen the thumb screws on the oxygen tank (A), let the bolts drop down and remove cover, after which the parts which are within may be removed.

A charge of oxone may now be put into the holder (E) which is divided into compartments, arranged in spiral or step fashion.

Beginning with the deepest pocket, insert the oxone cakes edgewise, using tongs provided with outfit. Each cake will generate enough gas to run the burner five minutes, and from this it will be easy to determine the amount of oxone necessary for whatever length of time may be desired.

The user is cautioned to handle oxone carefully, as it is a powerful alkali similar in nature to caustic soda,



A—Oxygen Tank.
B—Cover to Oxygen Tank.
C-C-C—Thumb nuts and bolts for clamping down cover on Oxygen Tank.
E—Holder for Oxone.
F-G—Standpipe.
H—Needle Valve on top of Saturator for controlling the flow of hydrogen gas.
I—Water Cock.
J—Water reservoir. The weight of water in this tank gives the gas sufficient pressure.
K—Overflow for Saturator.
L—Removable screw cap on Saturator.
N—Main cock or valve for oxygen gas.
O—Needle valve on Saturator for controlling flow of oxygen gas to burner.
P—Inlet to Condensing jacket (which surrounds Saturator). In this chamber the moisture of Oxygen gas is condensed.
S—Outlet of condensing chamber. From this point dry oxygen passes on up to controlling needle valves Hand O.
S-V—Safety Valve, inserted in the rubber tubing on the Hydrogen Side to Plug T.

Fig. 128

strong lye, or potash, which would be very irritating if it came in contact with the skin. Do not touch it with the fingers, or with paper, cotton or woolen fabric, or other similar material, but handle only with wire tongs provided with the outfit. Equal care must be exercised in the matter of allowing the hands to come in contact with the solution which is formed from the combination of water and oxone. Such portion of the cakes of oxone contained in the sealed tin can as are not placed in the oxone holder must be protected from the action of the atmosphere. When the oxone is left open to the action of the air it soon absorbs moisture and rapidly deteriorates.

After holder (E) has been charged with oxone place the holder in tank (A). *See that the rubber gasket or washer is in place in the groove around the edge of cover* (B), place cover on tank, place bolts (C-C-C) in slots in the cover and tighten the nuts, giving the same reasonable and uniform pressure, so as to prevent escape of any of the oxygen gas. The two sections of standpipe (F-G) having been previously screwed together, the standpipe should then be securely screwed to cover (B), *care being first taken to see that the rubber gaskets are in place so as to secure a gas-tight union.* Now place the reservoir tank (J) in position, screwing it on the top of the standpipe, *make sure that the main valve or gas cock* (N) *and the water cock* (I) *are closed,* then pour clean water slowly into top of reservoir (J) until the level of same is within about two inches of the top of reservoir. About two gallons will be required. After the light has been started the water in reservoir will slowly sink into lower oxygen tank (A), and it will then be necessary to refill the reservoir (J) with water up to within about two or three inches of the top. *No more water will then be necessary during the run.*

To Fill Saturator.—(*This should never be done near a flame or fire.*) Remove plug (T) and also the overflow cap (K). Insert funnel in opening at top and pour in slowly sulphuric ether until it begins to overflow at (K). While filling, it is, of course, necessary to keep the saturator in an upright position. About *ten fluid ounces* will be required when saturator is charged for the first time. After filling, replace the cap screw (K) and the plug (T), securing same firmly in place. It is advisable to fill the saturator, say thirty minutes or so before using, so as to permit the fluid to thoroughly saturate the interior packing. When gasoline is used make sure that nothing of a lower grade than 88 degrees is used. This cannot be obtained from drug stores and can only be had in a few of the large cities from responsible dealers in stereopticons, etc., and when ordering be sure to state that it is to be used in a saturator. Where there is any doubt as to the quality of the gasoline it is advisable to use ether, which may be obtained anywhere. Do not change from one to the other without first drying out the saturator and filler thoroughly.

The location of saturator on upright standpipe is best understood by reference to illustration.

Now make sure that all valves are closed (N) (H) and (O) and then connect piece of rubber tubing from (N) to (P) and a shorter piece from (S) to (U), taking care to see that the tube is not kinked so as to choke the flow of gas. If the ends of tubing are first moistened with soapy water, it will be found easier to slip them on in place.

The burner in lantern may now be connected to saturator at outlets (T) and (O), as follows: The metal connection (S-V) inserted between the two pieces of rubber tubing is a safety valve similar to hydrogen plug (T), and is used with the short piece of rubber tubing next to the jet on the left hand side of the calcium jet or burner. The opposite end of the longer piece of tubing being attached to the hydrogen plug (T).

The longest piece of tubing is attached to the oxygen cross valve (O), and to the right hand side of the calcium jet or burner. Put a fresh lime in burner, allowing a space of about 3/16 of an inch between surface of lime and terminal of goose neck (or outlet).

To Start the Light.—Open the main valve (N), then slowly open the needle valve (H) on top of saturator, and apply a lighted match to burner, allowing the flame to extend two or three inches above the tip of the burner, then slowly open needle valve (O) until the gas from that source forces the hydrogen flame gently against the lime. Several minutes will be required to permit the air (which is in the oxygen tank at the start), to pass through the burner, after which pure oxygen gas begins to form and pass to the burner. The light will then become brilliant, and its maximum power may be obtained by adjusting the valves (H) and (O), until hissing is stopped, and the surface of the lime presents an intensely brilliant spot of light.

Notice—We advise the use of ether only, as 88° gasoline is no longer made.

USE CONCENTRATED ETHER ONLY

The supply of saturator gas to burner should be a little in excess of the oxygen. The presence of a small fringe of reddish flame at lime will indicate this.

Hissing or roaring is caused by an excessive supply of one or both gases, and can be stopped by adjusting the needle valves. When the proper adjustment is secured, the light will burn with but little or no attention. After the outfit has been used once or twice the operator will have no difficulty in securing a beautiful, steady and brilliant light.

Snapping and popping is caused by too great a supply of oxygen and not enough hydrogen, or it may be caused by the fluid supply in saturator running low. About four ounces of fluid per hour is required in saturator, and it is advisable *to fill saturator each time it is used,* taking care, of course, to see that overflow screw (K) is removed while filling. Should one of the rubber tubes be blown off with a loud report it is almost certainly due to an empty saturator. While the effect is harmless it is apt to startle an audience, and for this reason it is well to see to it that saturator is properly charged before beginning an exhibition.

When through with the light turn off the main valve (N) first, then the needle valve (O) and lastly (H). A series of short, snapping sounds may occur when light is extinguished, but these are harmless. This is due to the small amount of gas remaining in the tubes which comes in contact with the hot surface of the lime. Also disconnect burner tubes from saturator. If through with the light, drain off water (if any), from water cock (I), disconnect tube from valve (N) and unscrew reservoir (J). Now disconnect rubber tube at (S) and slip it over plug (T); this prevents any ether vapor escaping when saturator is not in use. Now unscrew the standpipe (G) to which saturator is clamped, and drain out through (S) any water which may have formed in the jacket surrounding the saturator.

The iron cover on oxygen tank (A) may now be removed, and the tank emptied, after which it should be rinsed out in running water, and wiped with an old cloth. The standpipe and reservoir (J) should also be rinsed out and wiped, and all parts kept clean and dry.

Be careful at all times not to lose the rubber gaskets or washers, which are necessary to prevent leakage.

Also be careful to see that lead gaskets at (K) *and* (T) *are in place.*

When setting the apparatus up for use, make sure that these are all in place, particularly the large rubber ring fitted in recess of cover, which should be flat and even, and not twisted.

After saturator has been used a dozen times or so the interior filler made of a roll of white flannel should be removed and dried out in the sun out of doors away from flame or light. This is advisable for the reason that gasoline and ether contain a certain amount of non-evaporating substance which remains in saturator and accumulates by repeated use. The lower cap of saturator may be removed by applying wrench at (L). *When this cap is* *again replaced make sure same is started right on the thread. This is important in order to secure a perfectly leak-proof joint.*

Extra flannel fillers for saturator, each............ 75c.

Material used for generating the gas:

Oxone, per can of 16 cakes..................$1.35
Sulphuric ether (pure) in sealed pound cans... .65
Limes, 7/8 in. x 2 in. in cans of 12............ .90
Limes, 1 1/4 in. x 2 in. in cans of 12........... 1.80
and water for the upper tank.

We recommend the use of 1 1/4 in. limes, as they admit of a larger field of incandescence and consequently project a brighter light of greater power than the smaller limes and last fully two-thirds longer than the smaller limes.

It is advisable to use jet (burner) of small bore. Not larger than No. 56 drill gauge. Large bore jets waste gas and do not improve light.

At the above cost of renewals the expense of operating calcium jet is from 90 cents to $1.00 per hour for either stereopticon or moving picture machine.

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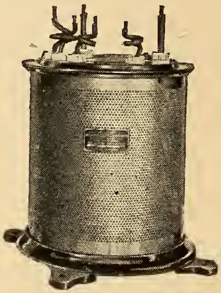

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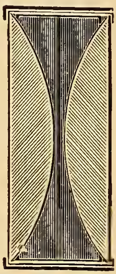

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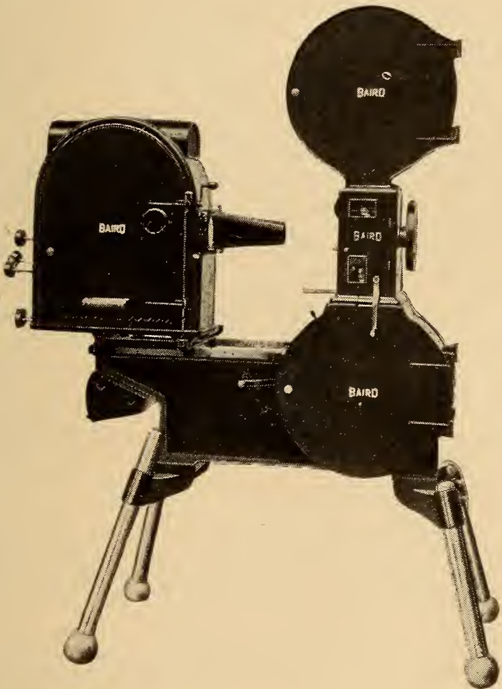

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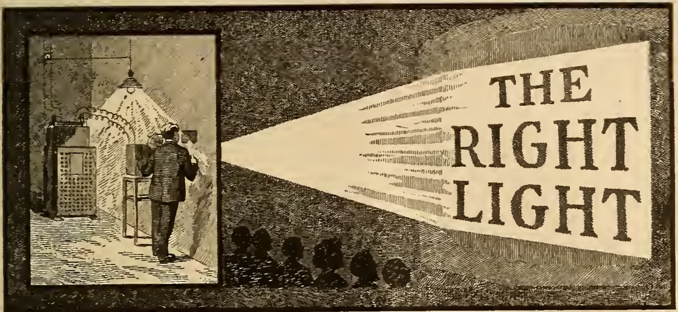
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