THE LINEMAN'S HANDBOOK

BY

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PREFACE TO THE SECOND EDITION

After fourteen years of service the first edition of this handbook is still filling an almost undiminished demand. Because of this unusual vitality, the author felt duty bound to revise it. Moreover, in the meantime, many changes and developments took place; lightning arresters underwent a complete change, and circuit protective devices were greatly improved. In addition, rural lines came into prominence requiring many new linemen. Pole-top resuscitation was introduced to shorten the time required for the application of artificial respiration. Furthermore, the National Electric Safety Code went into its fifth edition. These and many other changes prompted this revision.

Briefly, the new features included in this edition are:

1. *Rural Lines.* One chapter dealing with the construction of rural lines, and another giving the REA manual of operation and maintenance practices.
2. *Pole Top Resuscitation.* A complete account of the steps to be followed in applying this method of resuscitation.
3. *National Electric Safety Code.* All references to the code refer to the fifth edition.
4. *Tower-line Erection.* A series of illustrations showing the process of erecting towers by the "section" method.
5. *Safety.* Reprint of the publication entitled "Safety in Overhead Line Construction," prepared by the National Electric Light Association.

Safety is again emphasized throughout the book. Understanding the principles involved in any operation and knowing the "whys" and "wherefores" are the best aids to safety. A careful study of these pages should help much to make every lineman safety-conscious. The importance of safety was well stated by Mr. A. B. Campbell, Secretary of the Accident Prevention Committee of the Edison Electric Institute, as follows: "Every workman concerned with electrical circuits and equipment should realize the necessity for performing his work safely. Experience shows that in those organizations where the best safety records have been made, the best workmen are the safe workmen. This applies particularly to linemen. The opinion is now becoming firmly established in many organizations employing linemen, that a man is not a good lineman unless he does his work safely. It therefore behooves those engaged in line work to become familiar with the safety rules and precautions applicable to their trade and make their observance an inseparable part of their working habits and procedure."

In addition every lineman should become familiar with Part 2 of the National Electric Safety Code entitled "Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines." These rules, known as Handbook No. 32, give the minimum construction requirements in order to ensure safety to linemen and the public. A copy of Handbook No. 32 can be secured from the Superintendent of Documents, Government Printing Office, Washington, D.C., for a small charge.

E. B. KURTZ.

IOWA CITY, IOWA,
May, 1942.

PREFACE TO THE FIRST EDITION

This is the first book that is written expressly for linemen, foremen, and other employees of line departments. The lack of a suitable home-study book for linemen, covering construction and maintenance procedure and methods, has been generally recognized and was made the object of special mention by the 1920 Overhead Systems Committee of the National Electric Light Association when they said in their report:

There seems to be a growing requirement for a small pocket book on line construction, especially designed for the use of foremen, linemen and other employees of line departments. This book, while not covering many local practices, would tend to establish more desirable general standards, and it would serve to act as an intelligible guide to those unable to make practical use of more elaborate and technical books. Probably this type of book will be needed, even if the Handbook on Overhead Line Construction is revised; and it will become a real necessity when the proposed code of the Bureau of Standards is issued. It is for the latter reason that it might be well to decide upon the formulation of this book after the published form of the code is known. Such a book, or one similar in size and design, could be made to include instructions and other information on plant maintenance and operating features. It is thought that these branches of the work are worthy of more attention than they have previously received, either in company literature or other publications.

Acting upon this suggestion the author endeavored to present in this volume the items mentioned above plus additional phases of the subject as mentioned below, to make a well-rounded treatment. Especial effort was made to present all discussions clearly and in simple language. Technical terms are avoided as far as possible; in fact, a reading knowledge of the English language is all that is necessary to understand this book. A large number of illustrations showing the various steps in the operations described is purposely provided to assist the reader in understanding the text. These illustrations should be considered as much a part of the manuscript as the text itself.

The author desired, however, that this book should not be limited to the treatment of construction and maintenance procedure and methods alone, but that it should also include such additional chapters as would make it a useful handbook for the lineman. To this end an introductory chapter on "Elementary Electrical Principles" is given. This is followed by a chapter on "The Electric System" in which an effort is made to give the reader a perspective of electric systems. In Chaps. IV to VII inclusive, the various materials and equipments used in transmission and distribution are described, illustrated, and their use or operation discussed. Chapter VIII is a simple treatment of the factors governing line design. The object of these introductory chapters is to prepare the reader for a better understanding of Chaps. IX, X, and XI, which are considered the "heart" of the book. These chapters on Pole Line Construction, Tower Line Erection, and Inspection, Testing and Maintenance, however, are independent, so that a reader may confine his entire study to these chapters if he chooses. A comprehensive treatment of First Aid is given in Chap. XII. The book concludes with the reprint of the Accident Prevention Course for Linemen in Chap. XIII.

Emphasis is placed on the National Electric Safety Code. The important requirements of the code are reprinted and incorporated in the text where corresponding topics are discussed. Local practices are largely omitted. Emphasis is placed on the code, instead, in order that the requirements of the code may become more generally known and in the hope that more general standards will be established.

The author wishes to express his indebtedness to the operating companies and manufacturers who kindly provided photographs and cuts, to Mr. Edwin Gruhl for encouragement received in undertaking the project, and to Mr. R. E. Hayman for assistance rendered in the preparation of Chap. IX.

The writer would appreciate receiving any material, criticisms, or suggestions from linemen, foremen, superintendents, or executives of operating companies that could be used in the improvement of future editions of this handbook.

STILLWATER, OKLA.
April, 1928.

EDWIN KURTZ.

INTRODUCTION

The importance to the electrical industry of the lineman and his work has not always been fully appreciated in the past. The Overhead Systems Committee, quoted in the preface, remarked "that these branches of the work are worthy of more attention than they have previously received, either in company literature or other publications." This attitude accounts largely for the absence of books and company literature dealing with the lineman's vocation.

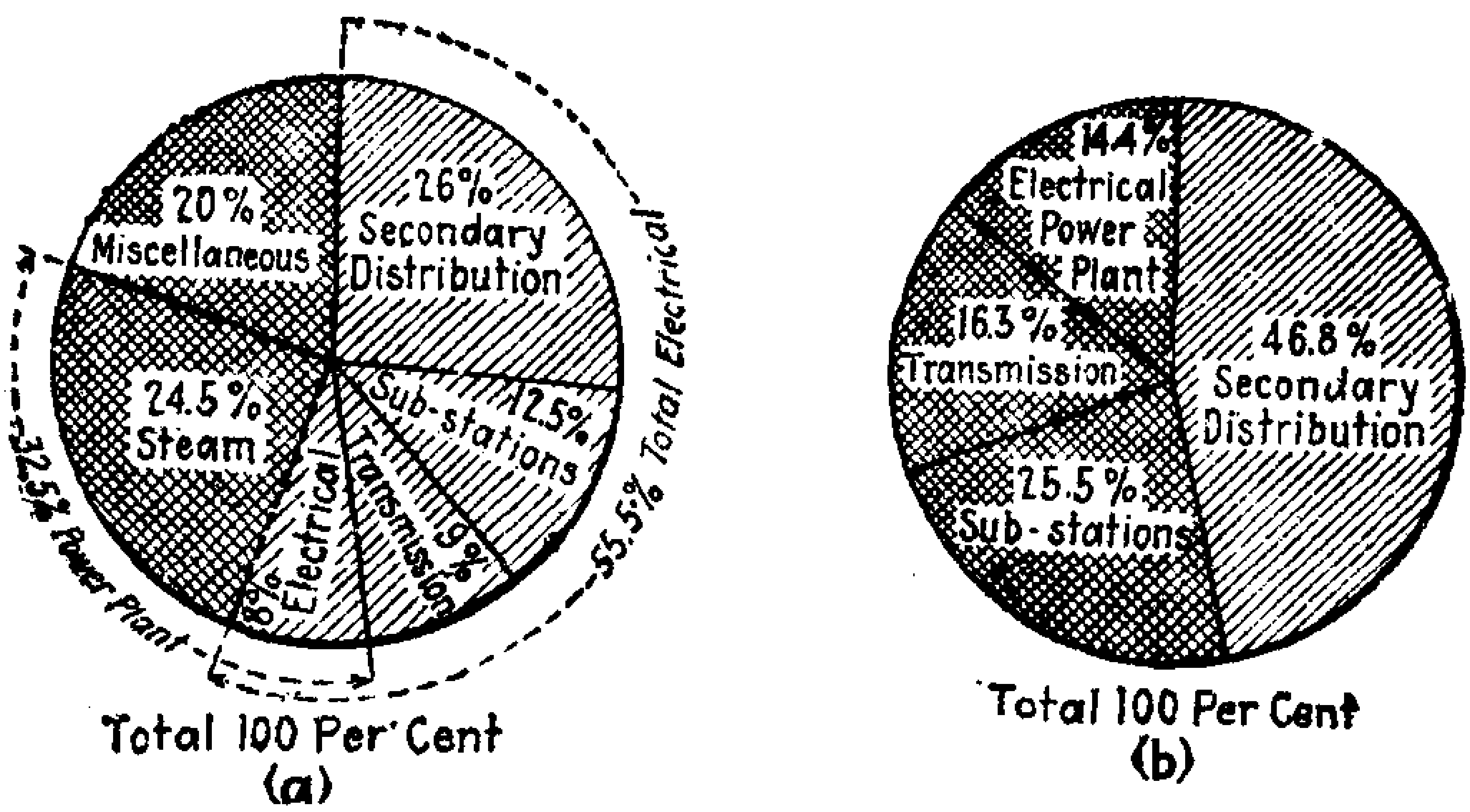

FIG. 2.—Charts giving distribution of investment in an average electric light and power company into its component parts as follows: (*a*) Total company investment. (*b*) Electrical investment only.

The importance of the subject of line construction and maintenance, which is the work of the lineman, may be brought out by a consideration of the investment in lines and substations in an electric property. To illustrate this point see Fig. 2 which gives, in (*a*), the division of the total investment in an average electrical property into its mechanical and electrical parts, and, in (*b*), the division of the electric part only into its component parts. Figure 2 (*a*) for example, shows that the total investment in the average light and power company is divided as follows: 24.5 per cent in steam, which represents mechanical, 20 per cent miscellaneous, and 55.5

per cent in electrical. This 55.5 per cent in turn is divided, in Fig. 2 (*b*), into 16.3 per cent transmission lines, 22.5 per cent substations, 14.4 per cent electrical power plant and 46.8 per cent secondary distribution system. Combining the items of transmission lines, substations, and secondary distribution systems, gives a total of 85.4 per cent which represents the portion of the electrical investment with which the linemen should be familiar. Omitting substations still leaves 62.9 per cent. In short, the lineman must know how to construct and maintain about two-thirds of the investment in the electrical part of our light and power companies. This is no doubt the reason why the committee said that "his work is worthy of more attention than it has so far received."

That much remains to be done in the future by the linemen is, of course, obvious. To make this evident, it is only necessary to note the mileage in electric lines in this country at the present time and to point out a few facts to show what mileage yet remains to be built. In 1937 the Census of the Electric Light and Power Industry reported distribution and transmission-line mileage in the United States as follows:

	Miles
Distribution line miles embracing voltages from 2300 volts up to but not including 11,000 volts	384,825
Transmission line miles embracing voltages of 11,000 volts up to and including 220,000 volts	178,521
Total electric-line mileage	563,346

This mileage would reach around the world at the equator about 22 times. All of this mileage must be continually inspected, tested, and repaired, and repeatedly replaced.

Many more miles, however, still remain to be built. Consider for a moment what it would require to reach every farmer in the United States. There are about 6,500,000 farmers in the United States and counting three farmers to the mile of line, there would be required over 2,000,000 miles of line to serve them. This rural mileage alone would reach around the world 80 times.

Then consider the many small communities in the United States that are still without electric service. Data are not available but an estimate would indicate that about 100 towns ranging in population from 500 to 1000 persons, and 3000 towns having a population of less than 500 persons are still without electric service. Most of these towns will undoubtedly be supplied with electricity in the course of time and the manner of reaching them will be largely by transmission line extensions from the 5235 existing electric systems. These lines will also be built and maintained by linemen.

The above figures illustrate convincingly the important part linemen will continue to play in the development and operation of our electric systems in the future. Every lineman and groundman can thus well afford to take steps to increase his knowledge of his daily work so that he will be qualified when the chance for promotion comes. Furthermore, an understanding of electrical principles and their application in electrical construction and maintenance work will do much to make the lineman's work less hazardous. These two reasons alone justify whatever time and effort is expended in studying these pages.

CONTENTS

THE LINEMAN'S HANDBOOK

CHAPTER I

ELEMENTARY ELECTRICAL PRINCIPLES

What Is Electricity?—No one knows. Ever since the day in 1753 when Benjamin Franklin drew a spark during a thunderstorm from the door key tied to his kite string men have been seeking the answer. The most educated men have studied electricity, but to this day it cannot be said that anyone knows what electricity really is. But by

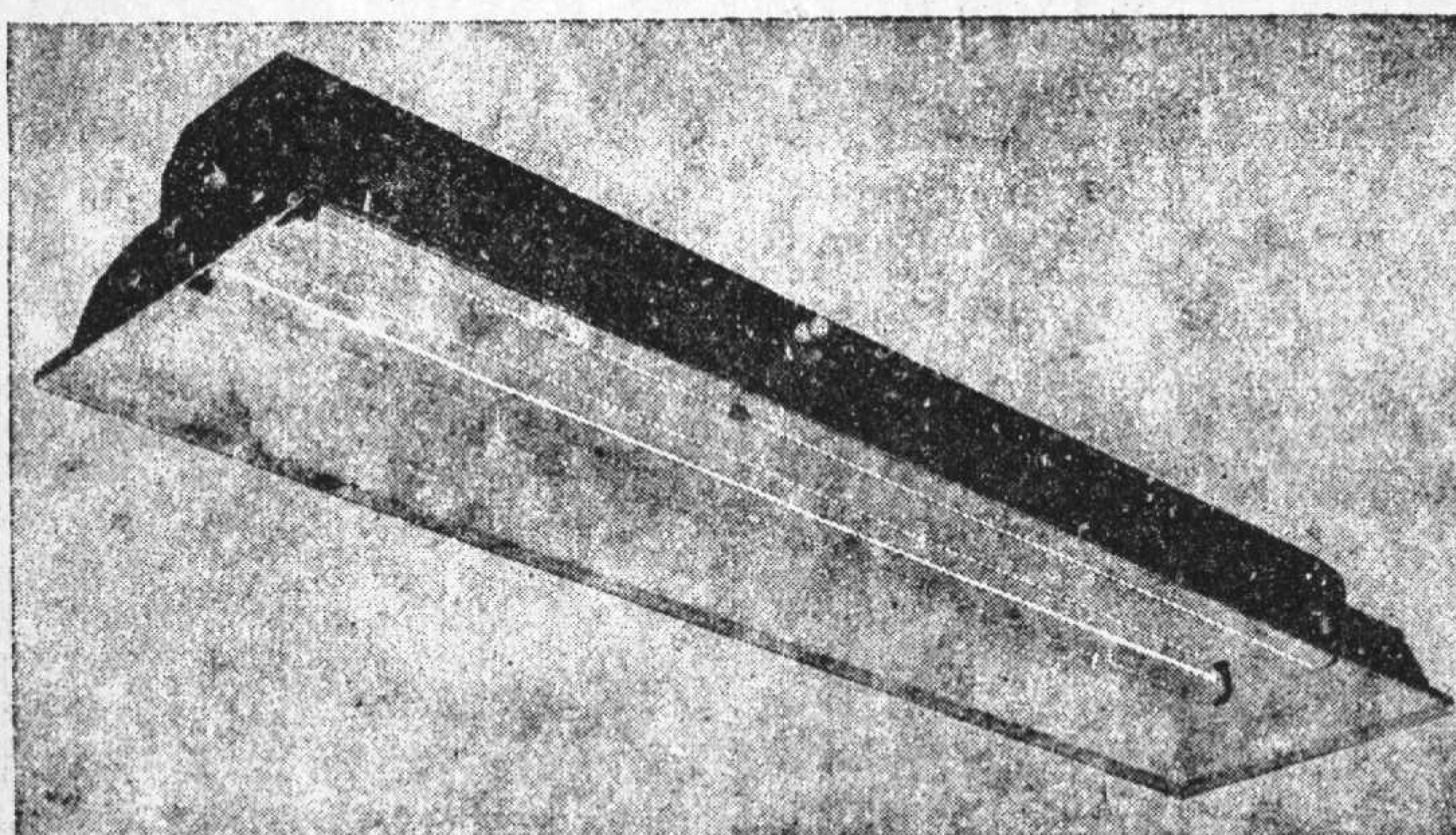

FIG. 3.—Typical fluorescent lamp by which electricity furnishes light. (*Courtesy Westinghouse Electric and Manufacturing Co.*)

all this study, these wise men have learned much about it; so much that today everybody knows what electricity can do. People have learned how to use it; and they know how to handle and control it. This, after all, is all that they are interested in. It makes little difference to us whether electricity is a liquid like water or a gas like air, provided we know how it can be generated, how it can be transferred from where it is made to where we want to use it, and the nature of the devices and apparatus in which it performs the desired work.

USES OF ELECTRICITY

Electricity today is used for very many different purposes. As a matter of fact, the uses to which electricity can be put are so numerous

FIG. 4.—Typical electric flatiron, in which electricity is changed to heat. (*Courtesy Westinghouse Electric and Manufacturing Co.*)

FIG. 5.—Typical bread toaster, in which electricity is changed to heat. (*Courtesy Westinghouse Electric and Manufacturing Co.*)

that one can hardly count them all. There are several general applications, however, with which everyone is familiar and these are given in what follows.

Electricity Furnishes Light.—Electricity, for example, is used to furnish light to nearly every home in the larger cities, to every shop and factory, and to light the busy streets of our cities. Everybody

FIG. 6.—Typical electric range, in which electricity is changed to heat. (*Courtesy Westinghouse Electric and Manufacturing Co.*)

is familiar with the fluorescent lamp shown in Fig. 3. In an electric lamp the electricity is changed to light.

Electricity Furnishes Heat.—Electricity is used to furnish heat. The electric flatiron with which the housewife irons the clothes is a device in which electricity is changed to heat. Figure 4 shows such a flatiron. Figure 5 is the picture of a bread toaster, another device in which electricity is furnishing heat. Figure 6 is a picture of an electric kitchen range on which complete meals can be prepared with electricity.

Classification of Uses of Electricity

Used as light in	Used as heat in	Used as power in
House lamp	Range	Streetcar motor
Street light	Flatiron	Factory motor
Arc light	Ironer	Elevator
Sign light	Glow heater	Refrigerator
Floodlight	Curling iron	Washing machine
Headlight	Toaster	Vacuum cleaner
Movie projector	Waffle iron	Kitchen aid
Flashlight	Water heater	Fan
etc.	etc.	etc.

Electricity Furnishes Power.—The largest use to which we have been able to put electricity is to furnish power. A very good illus-

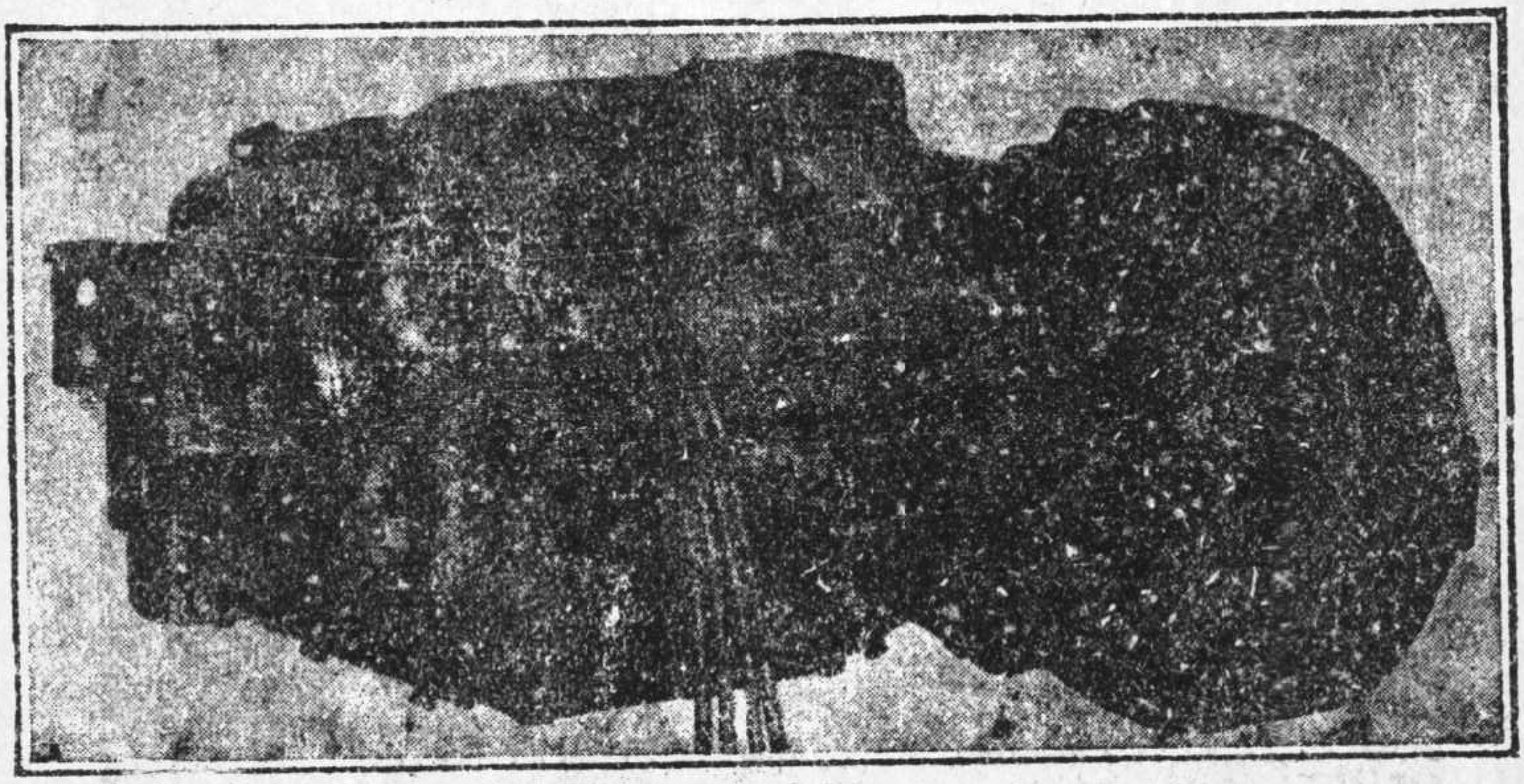

Fig. 7.—Typical street-railway motor, in which electricity is changed to power. (*Courtesy General Electric Co.*)

tration of a case where electricity is changed to power is the electric streetcar. Everybody knows that it takes force to move a heavy streetcar on a track, and the power required for this is obtained from the electric motor. Such a motor is shown in Figs. 7 and 8. When riding on a streetcar one generally does not see this motor but it is there. It is mounted under the floor of the car and is geared to the axle of the car as shown in Fig. 9.

Most of the large machine shops now use electric motors to drive the lathes, millers, planers, drills, punch presses, etc. One large factory may have several hundred motors installed like the one shown in Fig. 10. The parts of this motor are shown in Fig. 11.

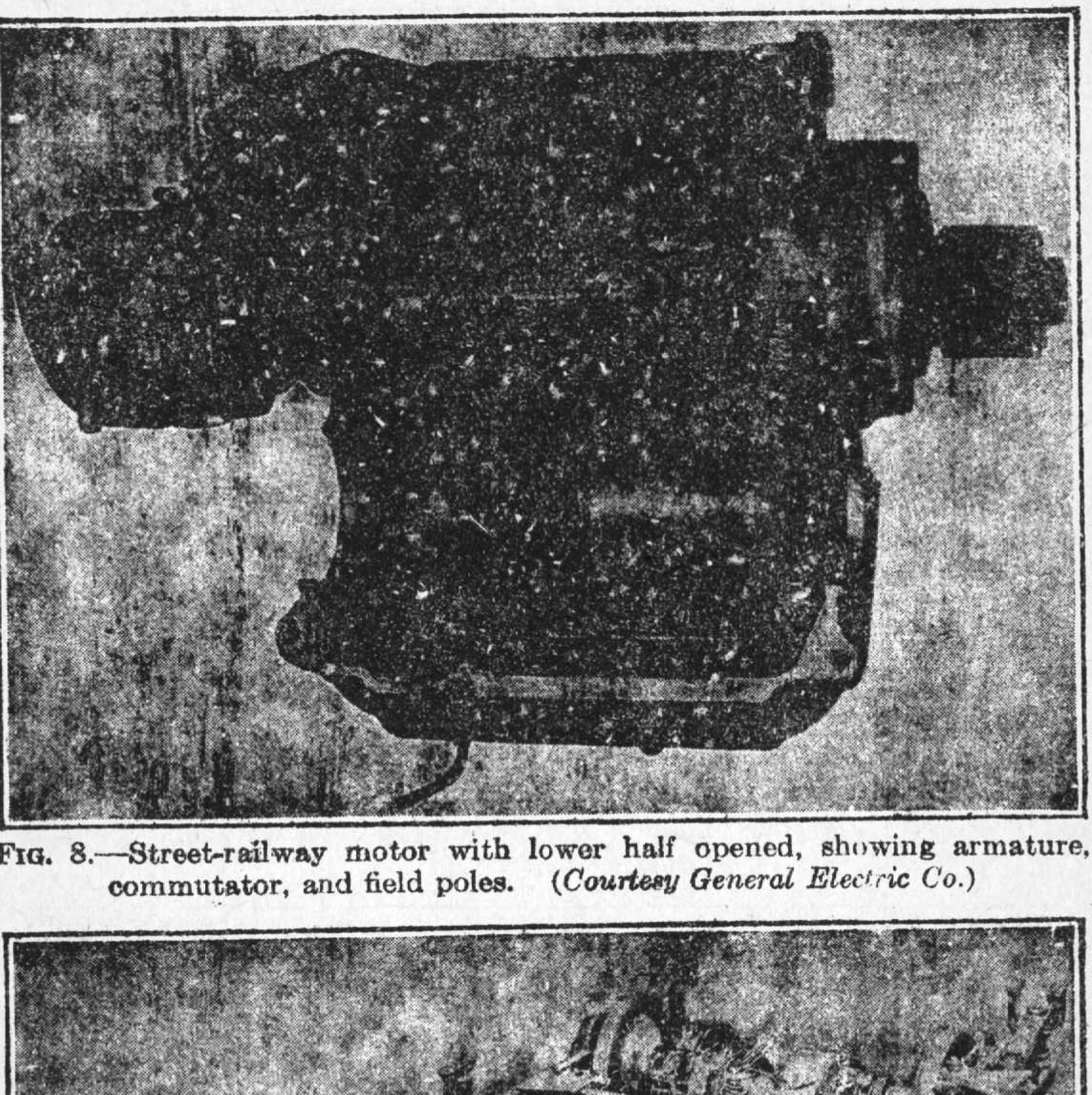

FIG. 8.—Street-railway motor with lower half opened, showing armature, commutator, and field poles. (*Courtesy General Electric Co.*)

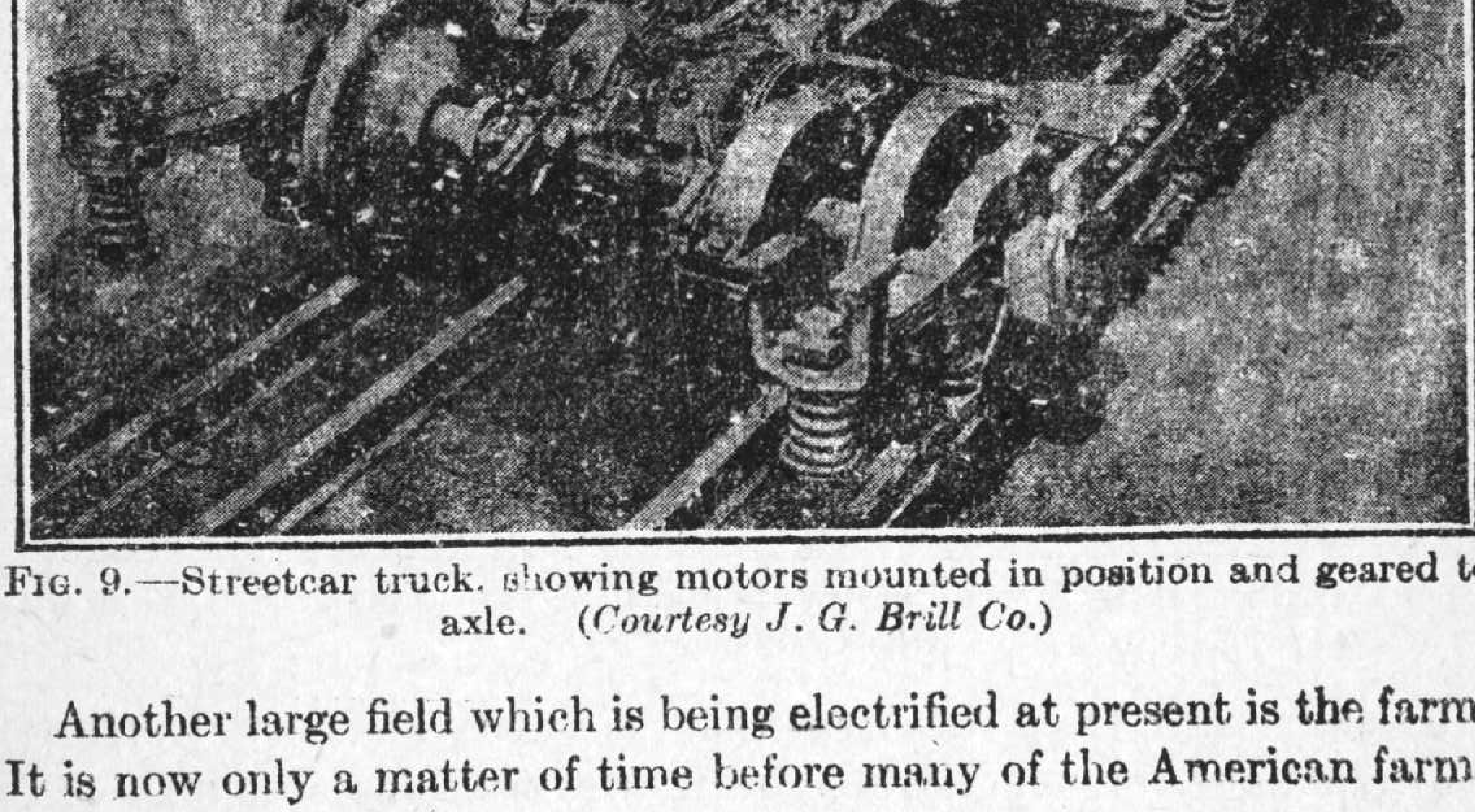

FIG. 9.—Streetcar truck, showing motors mounted in position and geared to axle. (*Courtesy J. G. Brill Co.*)

Another large field which is being electrified at present is the farm. It is now only a matter of time before many of the American farms will have all the electrical conveniences in the household and numerous small-sized motors in the barn, pump house, dairy, and shop.

FIG. 10.—Typical electric motor of the alternating-current type. (*Courtesy Allis Chalmers Co.*)

FIG. 11.—Alternating-current motor dismantled, showing parts. (*Courtesy Allis Chalmers Co.*)

To summarize, then, it is clear that electricity has many applications, the more common of these being the furnishing of light in our homes, shops, and streets, the furnishing of heat in our homes and industries; and the furnishing of power for our homes, streetcars, factories, and farms

ELECTRIC CIRCUIT

Compared to Water Circuit.—As mentioned in the first paragraph no one knows what electricity really is. At various times wise men believed that it was a form of matter. Some believed that it was a disturbance of the ether. Others contended that it was a kind of

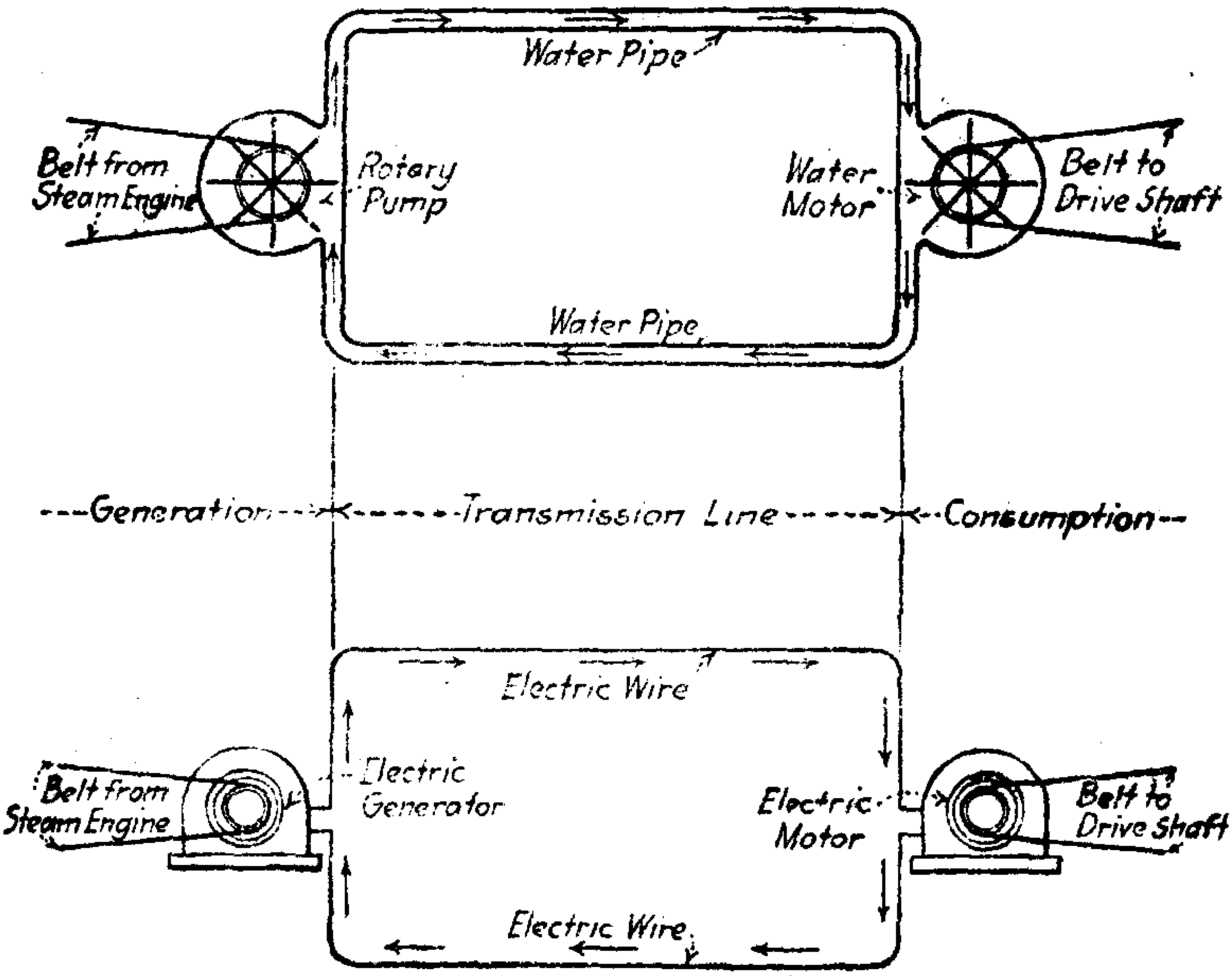

Fig. 12.—The water system.
Fig. 13.—The electric system.

force, and still others thought it to be a thin, weightless fluid. With these fancy speculations, this book, of course, has nothing to do. But the treatment of this subject can be greatly simplified if electricity is assumed to be a thin, weightless fluid. Such a fluid will then behave and act very much like water. Electricity can then be said to flow in a wire as water flows in a pipe. Everybody is more or less familiar with the flow of water in a pipe. Take a simple water circuit like the one shown in Fig. 12. By noting the resemblance between this pipe circuit and a typical electric circuit shown in Fig. 13 one can get a real understanding of the flow of electric currents.

In Fig. 12, water flows around the pipe circuit in the direction shown by the arrows. It is evident that this current of water flows because of a pressure which is exerted on it. This pressure is produced by the rotary pump, often called "centrifugal pump," which is driven by a belt from the steam engine. On the end of the pipe line, a water motor is connected in the line and, therefore, all the water that flows around the circuit must pass through the motor. It is plain that in so doing it will cause the motor to revolve and, therefore, deliver power to the line shaft by means of the belt. Similarly, when an electric current flows in a wire, it flows because an electric pressure causes it to flow. Thus, the current in Fig. 13 is made to flow because of the electric pressure produced by the dynamo, or electric generator, which is driven by belt from a steam engine. As the electric current flows along the wire it will be forced to flow through the electric motor. This motor will begin to revolve as the electricity begins to flow through it and thus also will deliver power to the line shaft.

Three Divisions of an Electric Circuit.—Each of the above circuits can be seen to consist essentially of three main divisions. The

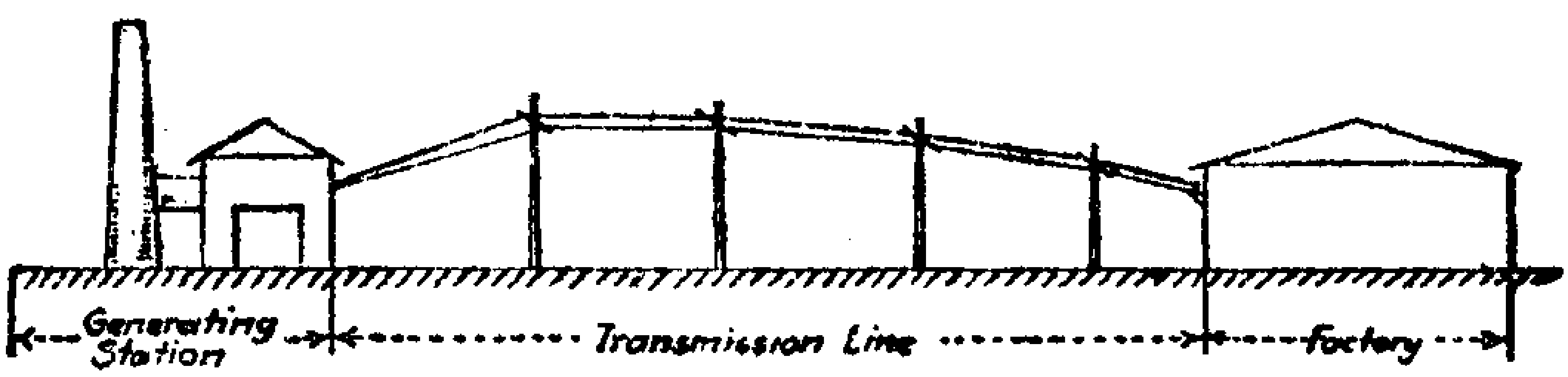

FIG. 14.—An actual electric system.

section where the pressure is produced, that is, where the engine drives the generator, is called the "generator section." That part of the circuit that furnishes the path for the current from the place where it is generated to where it is consumed is the transmission section, and the section where the electricity is used or consumed is the consumption or conversion division. Conversion means "change," and it is here that it is changed from electricity to either light, heat, or power. In an actual electric circuit like the one shown in Fig. 14, the three parts of the electric circuit are generating station, transmission line, and factory. The factory is the place where the power is consumed. Such an electric circuit is often called an "electric system."

The wires of the system serve to carry the electricity just as highways carry automobiles, and railroad tracks carry trains. The reason one does not see the electricity moving along the wires is because it is invisible. And while the wires and transformers appear lifeless, they are very much alive and willing and ready to do almost any work for us.

We should look upon the generation, transmission, and distribution of electrical energy as one does upon the manufacture, shipment, and