CENTRAL STATION MANAGEMENT

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PREFACE

It is the attention to details in Central Station management that marks the dividing line between profitable and unprofitable generation, transmission and sale of current.

It is the fair and cordial relations between the public service company and the public that establish the permanency of the Central Station.

It is the purpose of this volume to set forth clearly and simply those principles that are, to-day, adopted by the successful electric light and power stations of the United States.

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CENTRAL STATION MANAGEMENT

CHAPTER I

THE LIGHT, HEAT AND POWER BUSINESS OF CENTRAL STATIONS

The Rate Question.—Two or three points in the "Rate" discussion are more or less settled, or ought to be. One of these is the charging of a minimum rate in the ordinary consumer's home. The other is the charging of a graded rate according to the extensiveness of the supply. The other point of view to consider is that there are two sets of charges, fixed and variable in nature. One is distinct from the other because one charge is for service and the other charge is for current. This idea has not been properly regarded or understood by many who have had this problem in mind. The other point about it is that all customers using the same amount of current under about the same conditions are charged the same for it. So the developed idea thus presents itself in a simple and comprehensible form in the following manner as far as the service and current questions are concerned:

All Consumers of Current for Service

As the service is equal for all, the charge for service is equal for all. This is a responsibility which must be met at all times and is entitled to remuneration.

Heavy Consumers of Current for Current

The heaviest consumers of current are entitled to the consideration due according to the consumption and its effect upon and expense upon the station.

Medium Consumers of Current for Current

Consumers are classified according to the variable expense they represent to the station. Blocks of current may be sold according to such a basis.

Light Consumers of Current for Current

As this is but a light consumption of current, the cost is but little more than the service charge.

The introduction of the tungsten lamp has somewhat complicated the question. The public does not realize that light costs fundamentally a certain amount. Even though more light is produced from a given lamp than before at a greatly reduced current consumption, still the station is affected by a certain class of expenses which may ultimately force its managers to sell light instead of current, if the correct solution of this problem is to be found. In that case they would have to supply lamps, but to light consumers only, this would not be so difficult. As it is the common sale of current goes on to all, whether they use it for light or for power.

Light and Its Cost.— The question of light and its cost are natural and immediate, and may be regarded as of such importance that any means of reducing such cost to a fair degree is of public interest. But the cost of light produced by a central station is the pivot of the argument in any event, and the suggestions for cutting down this cost are all worth consideration unless examination proves the actual experiment unnecessary. Aside from experiments, the cost of light can be variously interpreted according to the contract made for the cost of current. That this charge may be larger or smaller according to the amount consumed is necessarily true. That it depends upon the character of the lamps employed is also to be understood. Then, again, the central station manager realizes that the operation of the station controls the cost of production, and that in this way also may be found an influence on the real proposition. Whatever the case may be and whatever the influences may be that determine the cost of light, the central station manager must have the power to control his expense so that a maximum is never reached in any instance. The cost of light received attention in the form of a paper on "Rates" read by Dr. John Hopkinson, F. R. S., in 1892, before the Junior Engineering Society of London. The idea growing at present in the public mind is that when money is paid out for current, it is really spent for light. Were the proposition within the limits of practical solution at present it would not be a bad thing to sell light direct instead of the power which produces it. This, however, is a proposition a little in advance of modern practise. The question of the cost of current has taken its place and is generally known as the "Rate Problem."

In the handbook of the Central Station Development Company, of Cleveland, Ohio, appears a statement as follows: "Dr. Hopkinson made it clear that the fundamental principles underlying any system of proper charging for *electrical service* and *current* required a fixed charge for the former and a charge per kilowatt for the latter. In 1900, Henry L. Doherty independently worked up the same thought, but carried it a bit further. Mr. Doherty pointed out that the fixed charge consisted of two components, one of which he called the *customer's charge,* which was the same for all customers; the other he called the *demand charge,* which, while not exactly the same for all customers, was essentially so, and was the same for all customers of given size and character. The Wright system of charging, based upon the *demand,* was widely adopted and rested upon the Hopkinson suggestion. Thus the Hopkinson, Wright and Doherty systems are the three in vogue in various forms." To recapitulate, it may be stated that the whole proposition hinges upon the correct interpretation and acceptance of the terms *electrical service* and *current* as understood by experts. Dr. Hopkinson makes use of the words, electrical service and current with regard to the rate problem. Mr. Doherty expresses his ideas by using the words, fixed charge, customer's charge and demand charge. Mr. Wright uses the expression, demand. The charge for service seems to be pretty well accepted on all sides as a legitimate and necessary charge, and has been sustained by the courts. The charge for current is the point at issue. — whether flat rates, differential rates or rates calculated and charged on the basis of circumstances shall prevail. It seems evident, that unless latitude is allowed on this score, a certain inelasticity will prevail in the transaction of business. Many concerns are apt to go into power generation themselves unless they can make a profitable arrangement with the central station. It would seem strange if such business should be lost, for the central stations and their managers are specialists in the care, management and operation of electric lights plants. For that reason they can compete with any proposal of a private nature, and assuredly can beat the price which practically amateurs in the field set up as a basis of competition.

Electric Heating. — The problem of electric heating is twofold: first, in the central station, and, second, in the everyday home. The central station is pushing the work tooth and nail to make the electric heating and cooking proposition inviting to the home owner. The manufacturers have their hands full showing the house owner that the time has come, as the saying goes, to change old lamps for new. As the change is a deep-seated one and radical in every way, the task for both parties is not enviable. The call now made for current in New York for electric heating and cooking is rapidly increasing. Statistics do not alter the facts, but only emphasize them. If it were necessary, every large central station manager in the country could show the rate of growth of the demand for current for electric heating.

The Heating Committee of the Association of Edison Companies, in a report made some years ago under the supervision of Mr. George Eastman, have the following to say: "The efficiency tests of various electric cooking utensils were made absolutely by the output in heating water up to the boiling point. Thus, by measuring the output with voltmeter, ammeter and stop-watch, and by taking thermometer readings of the temperature interval through which a weighed or measured quantity of water was raised in the given time making due allowances for changes in room temperature, not caused by the utensil itself, figures were obtained for the commercial efficiency. A general consideration of the results showed that electrical cooking apparatus of 70 per cent. efficiency can be readily obtained, and that special forms may even attain an efficiency of 80 per cent. Although the kitchen in which the tests were conducted contained only 1,400 cubic inches of space, none of the tests raised the room temperature more than one-half degree centigrade.

Commercial Efficiency of Utensils. — To obtain the comparative commercial efficiency of gas utensils, tests similar to those upon electrical utensils were made upon gas stoves in two private houses. Both stoves were of the standard type, having three single burners and one double burner on top, an oven below, and a boiler below the oven, and the kitchen in each case contained approximately 1,000 cubic feet. All efficiency tests were made with the gas cock turned full on, it being assumed that the excess supply of gas thus obtained best represented commercial practise. In computing efficiency, a calorific power of 600 British Thermal Units per cubic foot was used. The net results of the tests made were to give figures which showed that electricity would have to be sold at three cents per kilowatt hour to compete with gas. An elaborate article by Max Loewenthal, E. E., was published, giving full information on this subject to central station managers. The article is called, "The Present Status of the Electric Heating Industry," and appears in the *Electrical Record* of June, 1910.

Labor in the Cost of Cooking. — Electrical apparatus at from 80 to 100 per cent. efficiency offers a chance to the reflective mind to draw conclusions of great interest. Efficiency, after all, wins its way even though at times the conditions seem impropitious. There is a way of showing cheapness by considering not only the cost of the thing, but the amount of labor and inconvenience it involves. Labor to-day is the most costly element in really civilized countries. Even in lands where it was once so very cheap an awakening has come, and it is becoming an axiom to sociologists that in countries where human life is cheap, there also labor is cheap; and in consequence of this conclusion it seems inevitable that the countries leading in enterprise and civilization are those which must lead in their labor bills as well. But further developments will either strengthen this belief or give it the *coup de grace.*

At any rate, the idea involved is that cooking is an art of high order, involving time, skill and labor. Therefore, the invention which cuts down one or more of these items is the most valuable to society. Electricity has a road to travel in this respect which is of a peculiar character. Formerly a change in the household routine did not necessitate apparatus of a very complete or unique character. With electric heating utensils, however, the change is marked. There is no gas pipe and there is no flame; no soot or evidence of heat appears but the rise in temperature of the apparatus. The difference is therefore greater than appears at first glance, and unquestionably appeals to the imagination as well as the hand of the cook. Convenience is thus a great factor, safety another, and it can be shown that labor is a third, in favor of the electric cooking utensil.

But the vital fact is being presented on all sides to-day by the unprecedented demand for every electrical invention of proved value that is being manufactured. The fact that the public may question the cost of electric heating in no way alters the situation as regards the ultimate popularity of it as an established item of the home. Cost is an objection only when no marked advantages accrue. But when these advantages appear, the cost is not the objection that could otherwise be argued against it.

Kilowatt Hours for Cooking. — An average of 300 watt hours per meal per person is given as an allowance for electric cooking. In a family of five, four kilowatt hours per day is taken as an average. If the kilowatt hour means ten cents or five, the cost is considerably reduced. At the rate of ten cents per kilowatt hour five people are fed by an electrical consumption of energy estimated at forty cents per day. If the rate is five cents per kilowatt hour, the cost of the heat energy is one-half only, or twenty cents per day. The problem thus depends upon the money spent for power, other things being equal. Central station rates are not high, even though it might seem to some they are, because the cost of cooking seems high. In comparison it might be said, oil stoves are cheap to run, so are gas stoves; why, then, is the public showing favor to electric heating utensils? Simply because the statement must be made, with no offense to gas companies, that the public might as well be expected to use oil stoves in place of gas stoves when accustomed to gas stoves, as give up electric stoves in favor after the same lesson has been learned. Progress, after all, is the secret, and the public feel it by instinct as they do other things. For this reason electric heating must have its way whether we argue about it or not.

Cooking from a Sociological Standpoint. — In commercial and industrial discussions the point of view has broadened. The exact profit and loss consideration has developed into one more humane and more pertinent to human welfare. Concerns cannot make money as they once did; and people do not live as their ancestors did. Labor is being raised to a higher plane, because it has become evident that aristocrats are not the cream of the earth; but the producers, the makers of prosperity, are the real claimants thereto. The higher and lower classes are merging so rapidly that the lower classes want in proportion almost all the so-called luxuries of the day. And they are getting them, too. Electricity is the power that is making them accustomed to such things, and it is evident that once they use electricity for all home purposes, their continued use would readily turn them into necessities. This is what electric cooking is and will become. The cost of electricity is not the only item, for this is lost sight of to a large extent by the convenience. It is the fact that it is what progress calls for, and therefore must become general and popular.

The Power Problem. — It is easy to enumerate the sources of revenue of a central station of to-day. There is the domestic or home lighting to consider, hotel lighting, theatre lighting, the street lighting, the commercial lighting, the municipal lighting of buildings; the power for motors in factories and the charging of storage batteries for electrical vehicle service. The instrument employed for the purpose of developing these sources of power consumption is publicity. The publicity bureau of a central station is the foundation of this form of activity. In addition to the publicity bureau there is naturally the record of past work, which is a strong recommendation of future business. Under these headings the power supply problem can be considered.

1. *Domestic or Home Lighting:* This is partly found in private homes and largely in apartment houses. It is a growing business in New York and other large cities. Publicity helps it, but it has a natural and unaided growth.

2. *Hotel Lighting:* This is a necessity in modern hotels and is a well established branch of station work.

3. *Theatre Lighting:* No theatre uses gas to-day. Stage methods and insurance forbid it. Public safety demands the use of electricity. The power supply here is made necessary by the new methods and demands of the day.

4. *Street Lighting:* Electricity is the only effective weapon against street thugs and disorder on the streets. The public are accustomed to its use and this branch of service constitutes a distinct contract in central station work.

5. *Commercial Lighting:* Windows and stores are now lit exclusively by electricity in modern towns and cities. The publicity bureaus and competition have forced this issue and made it a custom.

6. *Municipal Buildings:* Courts, city halls and municipal buildings of all kinds are lit by electricity. This includes postoffices, where electricity is a necessity from an illuminative and sanitary standpoint.

7. *Lights and Motors in Factories:* Modern prac-

tice, which is after efficiency and output, finds electricity the only solution to this problem for light and power. Direct driven machines are the up-to-date way of running a factory to-day, if efficiency is in view. With this point of view goes good light as well.

8. *Charging Batteries for Electric Vehicles:* This is a comparatively new business and has the advantage of growing by its own qualities. In large cities the "electric" is the most flexible machine to use. Large department stores use them almost exclusively. Breweries, bakeries and coal concerns are adopting them. The battery charging business is rapidly growing. The demand for speed, heavy deliveries and clean streets almost ended the day of the horse for such work. For theatre and short pleasure trips the "taxi" and brougham are in constant use and demand. The growth of this business has been enormous and the central station has no need to fear of its possible diminution. It is evident that the rising price of gasoline will aid in turning merchants' eyes more and more in this direction. The general aspect of the power business is very good. It is dominating every field of industry, and the advertising and publicity bureaus are making its prominence and effectiveness better known each day. The central station is now an indispensable adjunct of city life in a municipal and civil sense.

CHAPTER II

OPERATING EXPENSES IN ELECTRIC LIGHTING

Electric Light Plants. — An electric light system devoted to private needs is called an isolated plant. An equipment devoted to public needs is called a central station. In many large manufacturing plants, covering acres of ground, requiring thousands of lights, a private lighting system would greatly resemble a public service equipment. In Pittsburgh many gigantic plants, privately conducted, so to speak, may be found in operation day and night. In Germany the Krupp steel works comprise a community comparable in size to a large city. An electric light system there would involve thousands of lamps and taps for motor circuits, and a large area to be illuminated. Consequently, it may be generally stated that there are two kinds of very large electric light equipments: one kind, superposed upon the houses and streets of a community called a town or city; and another kind, superposed upon an area which may be equally great, and suffering comparatively from the same degree of congestion as a town, called a manufacturing plant. Where the same general run of problems arise with public service and private plants of equal size, the technical difficulties are about the same. The adaptation of a system to a town's needs involves municipal questions of a complex nature. One of the features is the fixing of the price of current. Another, is that of having the current on tap at all times for all kinds of consumers, under about the same general conditions. This means a form of expense incorporated with the peculiar character of the work. As water and gas are always on tap, so must electricity supplied under the same conditions be on tap at all times. The agreement with the municipality necessitates night service for lights. In a private plant, however large, it is optional to run or close the plant down at night. There are no forfeits or fines or unpleasant forms of publicity to follow. Therefore, though plants may be of equal size and discharge equal services the very fact of their performing a private or public duty stamps them as distinctly different entities in management, and, in all probability, in the character of their individual expenses as well.

Cost of Installation Inside and Outside the Plant. — The relationship between the cost of the station or plant and the cost of the external equipment, is one, which when established, presents three conditions for consideration:

1. When the cost of the plant, comprising the building, engines and generators is equal to the cost of the outside equipment, including lines, poles, conduits, sub-stations, and other forms of apparatus.
2. When the cost of the plant inside is greater than that of the plant outside.

3. When the cost of the plant inside is less than that of the plant outside.

Where small equipments exist, or such equipments as are found entirely within the structure containing the generators, no such consideration need be given. A plant may be very large and still be self-contained. In central station service the object is to sell current at better terms than individual lighting plants can supply it to themselves. In isolated plant service the object is to try to produce it for oneself on better terms than it could be provided. As some great New York office buildings have over 50,000 lights, and one recently finished has 80,000 lights, it is evident that great questions of private plants versus public service are being and will be settled very shortly. The cost of a plant internally, as compared with the cost of a plant externally, is an interesting proposition to consider. Cost means investment, and investment means interest on a fixed sum. The fact is that the heaviest earnings must be obtained from the inside and the outside of a plant. Whether one or the other part as described is capable of making such earnings, is a point worthy of consideration. There are dead parts to plants as well as live. In purchasing, the excessive cost of a site, on which a prospective plant is to be erected acts negatively to the purpose for which the investment is to be made.

Bearing of Interest Charges Upon Dividends. — As the ostensible object of an enterprise is to make money, whether it be ice making, coal mining or electric lighting, it is evident that the charge for the use of the money required to establish the enterprise might so eat into the profits as to cut them down to a negligible sum. In all corporate forms of business, where investments are clubbed together, the joint earnings are divided after the legitimate charges have been paid. One of the continuous expenses of a plant run to make money is the interest on the operating capital. This capital appears in two forms: First, as the capital required to establish the business. Second, the capital necessary to keep it in activity. A plant is a source of expense until it pays its own expenses. However large a plant may be, until it has developed, established connections, obtained customers, and has a steady business, there is an outgo. This, in a sense, is dead capital, inactive or invisible money. It is true in practically every line of business until a supply of money is produced by the enterprise to run itself. If an excess exists, so-called profits can be paid. In a corporation a percentage of the value of the stock at par is regarded as the regular thing for disbursements at quarterly, semi-annual or yearly intervals.

If the building and its appurtenances, including ground and machinery, is too heavy an investment commensurate with the immediate patronage, only an extension of this patronage in the future would lead to a reason for its continuation. On the other hand, if the building, ground and machinery is a moderate investment, and the growth of business suggests and demands extensions outside, it is evident that such investments are reasonable, self-supporting, and financially creditable.

Some station managers follow a rule for such estensions of outside business. In one case, where extensions were demanded costing about $2,500, the manager requested a guarantee of $500 worth of business with which to start. This was preliminary to the additional business obtainable after the customers guaranteeing $500 were being supplied. A ratio of 5 to 1 in this case indicated a 20 per cent. return in earnings per annum. As 6 per cent. was needed for the ordinary investment, it is evident that 14 per cent. covered wages, wear and tear, clerical help, collecting, etc. In other words, a small station investment, and a large external investment, made in proportion to the development of business seem to fit the conditions properly.

The investment made to establish a business, to support it; the investment made for ground, buildings, machinery and appliances, and the needs which arise requiring the issuance of bonds, belong to the category of annual expenses, more or less fixed, which react upon the earnings. The cost of coal is an item, along with that of wages, in all, comprising a yearly sum of formidable proportions in a large installation. The ground, building, fuel, boilers, engines, and generators are earning money. The outside circuits are earning money. The employees and the indebtedness are earning and taking it. The dividends paid on stock is the sum left after a quarter, six months, or a year of labor and interest has been paid.

Part of Investment Producing Wasted Power. — A very heavy loss is sustained in large central stations with wide branching circuits, due to a double drain in a financial sense on the earnings of the concern. This is the loss of power daily sustained in mains and feeders extending over the town or city. In the case of a private plant of large dimensions serving a community, it is equally true. Probably 10 per cent. of the generated electricity is lost in transmission and distribution, and disappears as heat in the conductors. In some cases the percentage is less than this. In other cases it is even higher. The drain due to this is twofold: First, it means a loss of 10 per cent. of the earnings of the company; second, it means an investment on which interest must be paid as well as the rest. To avoid this loss, either high-tension circuits must be run between distributing points, or heavy conductors must be employed. High-tension alternating, two or three phase currents, help to cut down on the transmission loss, but constitute quite an investment when they are auxiliaries in the way of substations, as in New York. If, for example, in a $1,000,000 plant, one-half is spent as an investment on generating electricity, then, if 10 per cent. is lost, a $50,000 investment is wasted. This, at 6 per cent., equals $3,000 a year. This $50,000 worth of plant could also earn money by the same electricity, if that much were not wasted. Hence, it appears that $3,000 must be added to the value of the lost sales of electric power as well.

The Cost of Doing Business. — This broad proposition is of universal application. The cost of doing business is variously estimated. In the electric light industry, the cost of doing business can be calculated by comparing the gross earnings, or volume of business per annum with the year's expense. If new machinery, additions or other improvements had been made, then the cost of doing business that year would be high. But taking an average of years, and an average of annual expenses for each year, respectively, would give the information sought. One of the largest Broadway merchants states the fact as follows: "Having determined the cost of doing business (that is, the percentage of expense on a certain volume of sales), and in this you are entitled to figure a proper rate for depreciation in the value of stock and proper recompense for the head of the business, it then becomes a question, what is a legitimate return on the investment?"

This applies in electric lighting, where a distinct factor of depreciation exists. When a block of current is sold, 10,000 kilowatts, for instance, the question is this: How much of the earnings received for that power per annum is actual expense, and how much is profit? To illustrate: if a plant cost $1,000,000, the interest charge against this per annum would be $60,000. This is a distinct item.

If wages, fuel, depreciation, insurance, advertising, repairs, and a sinking fund cost $150,000, then the total cost per annum would be $150,000 + $60,000 = $210,000. If the gross earnings are $300,000 per annum, the net earnings would be $300,000 − $210,000 = $90,000. This amount applied on the stock representing the investment for the plan, that is to say, on the million dollars, would mean a dividend of 9 per cent., or as given, $90,000. The cost of doing business in this case is evidently $210,000 a year on an investment of $1,000,000; but as it costs this $210,000 to get $300,000 worth of business, the ratio is as 21:30 = 7:10 or 70 per cent.

In this case the stockholders are secured at the start, by making an allowance of 6 per cent. on the original investment of a million dollars. This is necessary, because of the new expenses that may arise, and the possibility of business falling off. Unusual weather conditions may do this, if the main business is lighting. The days may be bright during a period when more electric lighting is generally done. Or, if dependence is placed upon the power sales for motors, business depression may cut this down. The 9 per cent. dividend is not a certainty, but the 6 per cent. should be, as savings banks give from 4 to 4½ per cent., and first mortgages yield from 4½ to 5 per cent. with practically absolute security. In an enterprise of this kind, however, evidence of good management shows itself in the manner in which obligations are kept up during hard times. The good manager or financier makes provision for them always. The less astute and more optimistic executive is left in a very unpleasant position when the blow falls. Getting of plenty of business, and at a price which insures the company against present or future losses is the only safe policy to follow.

The Factor of Depreciation.— Depreciation means fall in value or usefulness. As a general rule it is used to demonstrate reduced usefulness through wear. Did it mean reduced usefulness alone, then whether wear occurred or not, the fact that something better had appeared would militate against it. It would be folly to attempt to compete with defective or old-fashioned apparatus. In the last thirty years great changes in this respect have taken place. Three or four different kinds of engines, generators and switchboards have been installed and removed from large central stations. New inventions and improvements in the system have led to this. To gain and hold efficiency, it has been necessary to make these improvements as required. Depreciation may therefore mean the "wearing out" of things, but in electric lighting it can include apparatus "behind the age" as well. After ten years machines become defective from natural wear and tear. In twenty years they are apt to prove unreliable. An allowance of 5 per cent. for depreciation would not be excessive. A million dollar investment could easily have a $50,000 yearly item in this direction, on an allowance of twenty years life to the operating parts of the plant. This sum added to the interest of $60,000 would give a fixed expense per annum of $60,000+$50,000, or $110,000. Adding the other items of fuel and wages, insurance and publicity to this would greatly swell the cost of doing business.

Water-Power and Fuel-Burning Plants. — Every effort is made to avoid large investments in business which might prove eventually to be dead capital. There are few industries which escape this misfortune. Even the most astute of our financiers are taken in every now and then and led to making heavy investments where it is seen afterwards a loss is inevitable. As an example of this form of error, the street railways of New York were equipped for steel cable at an expense of over $100 a foot of track in some parts. After a comparatively brief period of use, this cable system was torn out, and the present electric open-conduit system installed. This meant an enormous loss, but had to be met, to give the people of New York a satisfactory transit system.

In the installation of an electric light plant many questions arise. Government tests have shown that low grades of coal, put through a producer-gas system, can be used for power with gas engines. No boiler being required, an item of wear and tear is removed. Storage tanks for gas take their place. Apparently the plan is one of great importance, and is being tested in Germany and this country. The Diesel engine with its enormously high-efficiency factor is coming into popular use. Efficiency in output means reduced investment. This is a form of financiering that is being greatly encouraged at present.

With a water-power plant, the energy of the water is a constant and reliable product. A heavy investment cannot be escaped where the plant is large. As a rule, in large plants, dams and tunnels have to be built to last. But a large investment, where a permanent output is a certainty, is an allowable move in finance. Judging from the magnificent plants of hydro-electric design in operation at Niagara, and the West, enormous sums of money were invested before a wheel turned.

It is evident that power is not obtained for nothing. While nature produces the power of the falls or rapids, great sums of money must be spent before this power is safely and economically available. The interest on this investment is the cost of the power plus the annual cost of labor and skill to manage it. The advantage such plants have is, that of opening up barren districts. As a consequence the power is now contracted for before it it generated. As such plants are not subjected to the variable market conditions governing the price of coal, in other words, as the price power costs them is fixed, the financial proportion is a simpler one.

The care of the outside lines and circuits would be the same as that of any other plant. In the power house or central station, there would be no boiler or engine-men. The labor bill there would be very much less. There would be no fuel bill. The elimination of that would be an item of importance. The deterioration of the plant in general would be less, but the investment being a heavy one, as a whole, would reduce down to a definite proposition as follows: A certain sum laid out for the plant, complete; a yearly bill for labor; a yearly bill for extensions in circuits at points of distribution. As in a fuel-burning plant, a calculation based upon a comparison of the annual expense with the annual earnings would show what it costs to get business. Although the phrase "power for nothing" has a fascinating and magical influence over some minds, it is quite clear that a constant cost is attached to it, due to the extent of the investment necessary, and the interest charges must be paid out of the earnings.

CHAPTER III

STATE PROTECTION FOR LIGHTING COMPANIES FROM COMPETITION

State Regulation of Rates. — The State, in our present form of twentieth century civilization, has assumed a paternal attitude to the public. It has stepped between purveyors and consumers to protect the latter from the former. Like King Canute of old, it seems to sit at the shore of commercial development and say to its rising flood, "Thus far shalt thou go and no farther." This has been manifested in the case of electric lighting interests most emphatically of late. The State has regulated the rates charged. As an expression of public opinion in this democracy, of which the State is an authentic part, it, like all other of its opinions must be accepted. One of the characteristics of a republic is that no one man can rule. The autocratic instinct in a potential dictator cannot find expression without public consent. The individual cannot tyrannize and last. Yet in place of a single dictator — an individual — is found a collective dictator, the majority vote. But to date, no invention of man beneficial to human society, can approximate the benefits of the great American Commonwealth. It is built up of parts, called States. And at present they regulate the issues between producer and public, when that producer occupies the position of one popularly called "A Public Service Corporation." Now, as a matter of justice, the fixing of a rate, carries with it another implication. If that rate is fixed without the consent of those producing the commodity required, then the State or Commission establishing it as a maximum, ought to protect the interests affected, from a form of competition that threatens to destroy them. As one of the important decisions of the last twelve months, this idea of justice owed, has taken possession of the minds of those representing State rate boards and appears in the form of the following paragraph: "During the past year, a number of Utility Commissions in the various States have recognized the fact that with regulation and control of public service companies by Statute, the public utilities in return are entitled to look to the State for protection from competition." In the extreme desire to please the popular will, it is not difficult to pass beyond the bounds of justice, and commissions desirous of avoiding such uncivilized procedure, must be composed of men eminently fitted by temperament and education to see truth and justice unblinded by passion or prejudice and act accordingly.

Huxley's Opinion on the State's Function. — As one of the greatest of our thinkers, generous, just and free in his opinions, it is interesting to hear what Thomas Huxley has to say on the situation presented to-day: "I am as strongly convinced as the most pronounced individualist can be, that it is desirable that every man should be free to act in every way which does not limit the corresponding freedom of his fellow-men. But I fail to connect that great induction of political science with the practical corollary which is frequently drawn from it: that the State — that is, the people in their corporate capacity — has no business to meddle with anything but the administration of justice and external defense. It appears to me that the amount of freedom which incorporate society may fitly leave to its members is not a fixed quantity, to be determined *a priori* by deduction from the fiction called 'natural rights'; but that it must be determined by, and vary with, circumstances. I conceive it to be demonstrable that the higher and more complex the organization of the social body, the more closely is the life of each member bound up with that of the whole; and the larger becomes the category of acts which cease to be merely self-regarding, and which interfere with the freedom of others more or less seriously." Consequently it is necessary for those placed in positions of power, however temporary, to be extremely careful of the conclusions they draw from circumstances, industrial situations, review of policies, commercial or otherwise, and particularly of the rights of organized business. Taking away rights from such, means giving rights to others. It is evidently unjust to deprive an organized body, because of its organization mainly, of such privileges as are possessed by unorganized bodies, discriminating between the two and even hampering the freedom of the former because of this said organization.

Some Important Recent Decisions. — This idea is spreading throughout the country, and commissions are acting upon it, by giving protection to those limited in rates by statutory decree from the keen fang of competition exercised by others and from which they are unprotected. The National Electric Light Association, in one of its pamphlets expresses the thought as follows: "It would seem that heretofore as though this proposition has been lost sight of in a great many instances by regulating bodies and we are glad to note that the commissions and the courts are beginning to realize the fact that if regulation as to rates and service and capitalization are to be imposed upon utility corporations, they in return must receive something from the State in the way of protection. If monopolies are fostered by regulative laws, they must be protected from competition. It does not seem to be reasonable to limit the profit to be earned by a public utility and still permit it to be harassed by a competitor. The theory of protection seems to be spreading with the theory of regulation. It is hardly necessary for us to direct attention to all of the decisions during the past year in which the principles have been recognized and reiterated." It is thus evident that the act of the State against one group in curtailing its liberties, naturally emphasizes the effect of these natural liberties held by others against those in whom they are curtailed. If the State holds down the price of a commodity sold by one unit, for such an organized body as a whole can be held to be, but permits all other units free competition, it seems as though the State is thus inviting disaster to the business of the unit which happens to be thus organized. Cases have naturally arisen in which this conflict of rights and ideas have been settled in the courts. The Public Policy Committee of the National Electric Light Association has outlined the discrimination to be made in cases where the Public Service Commission of a State failed to make provision against unjust competition to a concern whose rates were regulated. A case in point will now be given.

The Failure of a Competing Private Plant to Obtain Public Service. — The cart may be put before the horse in this case by citing the conclusion of the Public Service Commission, First District, State of New York, and then giving the circumstances. The statement of the Commission is very reasonable and touches vitally upon the question of competition between two units: one limited by law in the extension of the rates, the other free to charge, in a measure what it pleases: "We think it is obvious that it would not be reasonable or proper that one supply company be required to furnish stand-by service to another and to take over temporarily the duty of supplying its customers, particularly when such company would find it inconvenient or even expensive to supply them. When applied to two large companies serving the same area and competing for supremacy, the unreasonableness of the suggestion be comes apparent."

The Unhampered Private Plant and the Regulated Public Plant. — The case on which the Commission passed the conclusion given was one in which a private plant as one unit demanded current from a public plant, another unit. The first, however, had been competing with the second by selling current. This is possible if it is transmitted within the limits of the block as was the case here. The facts as given by the National Electric Light Association are as follows: "In the case of Frankel Brothers against The New York Edison Company, the complainants owned a building on 32nd street, in which was located a private plant. In the rear of this building was another private building, the Phipps Tenements, formerly a customer of the Edison Company, to which Frankel Brothers supplied current from their private plant at a lesser rate than that charged by The New York Edison Company. Frankel Brothers contracted with The New York Edison Company for a break-down service, and when it was discovered that they were delivering current to the Phipps Tenements in the rear of the building, the Edison Company notified them that they were violating the provisions of the contract and unless they ceased serving the Phipps Tenements with current the Edison Company would discontinue its break-down service to Frankel Brothers. Frankel Brothers refused, maintaining that the Edison Company must continue its service although they, Frankel Brothers, were competing with the Edison Company and reselling the Edison current.

The service was therefore discontinued and the complainants instituted a proceeding before the Public Service Commission to compel the Edison Company to continue the service. The Commission, however, held, that The New York Edison Company was not bound to supply emergency or auxiliary service to a competitor. That Frankel Brothers were competitors of The New York Edison Company and were operating a private plant and selling current to the owners of the building in the rear of their building, and were attempting to use the service of The New York Edison Company during certain hours of the day, so that they would be able to serve their customers without loss. The complaint was therefore dismissed." Thus the idea, that a unit forced to regulate its rate, is protected against competition by one not so enforced is a satisfactory evidence that the Public Service Commission is intelligently and justly performing its duty in New York.

The Court's Opinion as to Resale According to the Anti-Sherman Trust Act. — Buying current in bulk and reselling it is a way of competing with the lighting companies. Laws have been passed governing the resale of merchandise. An agreement relating to this resale has been regarded as monopolistic. The Anti-Sherman Trust Act of July 2nd, 1890, held that an agreement as to resale of copyrighted and patented articles was in violation of this act. A broad interpretation of the act has made it include all other merchandise as well. Three important deductions may be made from the general proposition included by this act with respect to the electricity of central stations.

1. These decisions (177 N. Y. 473; 231 U. S. 84; 209 Fed. 1007; 202 Fed. 225; 210 U. S. 139), are of considerable importance to electric companies in cases where current is sold in bulk to a customer who may dispose of it as he sees fit.

2. The supply company has no control whatever over a customer when once the electric current has been delivered to him.

3. He may dispose of it as he sees fit as to price and manner and method without restriction, provided he does so in his own building or within the confines of the block where the electric current is delivered to him.

Here it is seen where a national act runs perilously close to destroying the power of a light-producing unit, because of State regulation of its rates, to face successfully the competition of a unit not so trammelled. Laws of broad and universal application in the Nation, must not conflict with those having the same intent within the State. The Federal law, once passed, stands as a record of far-reaching opinion. A State law must harmonize with such or a conflict would be inevitable between the rights of States and the Nation.

What Rates Prevent Regulation? — The most pertinent of all questions is not what remedy to use after a failure in policy is evident, but what the medical world would term "prophylaxis" or the prevention, by means of which no remedy is required because the disturbing reason is anticipated and prevented. Regulation comes as the result of a general conclusion, crystallized as legislative action, that rates for a certain commodity, allied with the granting of a franchise, are too high. Why does the Public believe the rates are too high? Largely because inimical interests back up a reduction campaign or the increased popularity and greater sale of the commodity, attracts more attention with the consequent public belief that the concern is overprosperous. The ethics of the situation are simple and apply to all businesses. The idea is as follows: Any business should be conducted as though an active competitor was present. This is a means of fortifying a business against attack. That attack may come through violent competition, or an attempt to regulate rates. The ethics of conduct calls for constant co-operation between the various members of a community tending toward the common good and the elevation of society as a whole to a higher level. In business this is not only possible but necessary and inevitable to such as want to survive. Civilization has advanced in this country, and to-day the rights of the public are keenly accentuated in the press, the forum and legislative chambers. Labor has risen to a position of high dignity.

The old system, therefore, which made a strong distinction between the successful merchant and his employees, almost as between master and slave, is crumbling into dust. Business has to conduct itself along new lines and processes. It cannot afford to make a large profit on a public commodity of universal use and heap up a large surplus without calling down upon it public attention, criticism, and its usual sequel: Federal or State enactments regulating the rates or conditions under which an unusual surplus was gathered.

What Is Meant by "Going Value." — The idea that competition exists is the healthy and natural basis on which it should be conducted. Competition means a conflict, not a war of prices, as much as a struggle to obtain supremacy. The one securing an equal or a superior bulk of business is said to succeed. One expense almost lost sight of in a hasty review of costs in a central station business, is that swallowed up in developing it. One question of this kind settled by the Court of Appeals of the State of New York (in the Kings County Lighting Case) was as follows: "That a public utility corporation is entitled to a fair return on its investment on the value of the property used by it, *treating a reasonably necessary and proper outlay in building up the business as an investment,* and this amount must be considered in determining a fair rate of return to be charged." Thus the investment that is visible and the investment that is absorbed are considered. As these two spheres of investment, different but closely related, affect rates and therefore competition, it is evident, that State appraisements must be based upon their consideration. If the company is to get what it is entitled to in the way of a fair return, by those entrusted with this computation, the "Going Value" is of vast importance. One of the questions thus decided by the Court of Appeals is as follows: "'Going Value' is an element which is required to be determined as a distinct item from good-will in making an appraisement on which to compute the fair return to which the company is entitled. 'Going Value' for such purposes is an amount equal to the deficiency of net earnings, below a fair return or actual investment due solely to the time and expenditures reasonably necessary and proper to the development of the business and property to its present stage and does not apply to the value of physical property." Thus, the courts discriminate between the physical equivalent of money invested and the absorption of capital to give a concern "Going Value," which is not to be identified with "Good-will." This is very necessary in regulating rates, as at elimination or neglect would bring them down too low for a concern to profitably do business, so much of its invested and invisible capital being made unproductive.

Protection Against Unfair Competition. — Occasionally, because a democracy is not infallible, legislative action is passed which is a hardship to certain concerns. The recognition of this fact, however, often leads to an amelioration of their condition by a form of legislation annuling that which is injurious. Consequently lighting companies must be patient until the laws or usage that is being slowly born on their behalf becomes matured. Errors and setbacks are quite human in this respect, for a conflict for rights is now raging in our Federal and State legislative halls of vital importance to us to-day and to our descendants. Thomas Huxley in his famous essay "The Struggle for Existence in Human Society" states: "I am unable to see that civil society in anything but a corporation established for a moral object — namely, the good of its members — and therefore that it may take such measures as seem fitting for the attainment of that which the general voice decided to be the general good. That the suffrage of the majority is by no means a scientific test of social good and evil is unfortunately too true; but in practise, it is the only test we can apply, and the refusal to abide by it means anarchy. The purest despotism is as much based upon that will of the majority (which is usually submission to the will of a small minority) as the freest republic. Law is the expression of the opinion of the majority; and it is law, and not mere opinion, because the many are strong enough to enforce it." Thus, though temporary ills flow from competition made unjust by one unit being legislated against and the other being free to act, it is evident, that in the end, an adjustment will be made, to protect the former and prevent the latter from acting unjustly in the future. Unfair competition, by its very existence is a crying evil, attracting attention, exciting public opinion, and thereby leading to legal or legislative action against itself. The law for lighting companies is becoming clearer and better, though lapses against them will occur and remain, until remedied by the means society employs for the correction of such evils.

CHAPTER IV

TECHNICAL FEATURES GOVERNING COST

Requirements. — Fuel, labor and management are the three essentials of station success, other things being equal. By this is meant and included the machinery, structure and system. Modern machinery would be up to the mark in construction, efficiency and usefulness. It would not mean the system particularly, whether alternating or direct or both but the newness and applicability of it to meet the new needs of the hour. The structure would of necessity be modern or the plant would fail in the handling of fuel and labor. The system would presumably be correct for the conditions, or the manager would be in difficulties at the start. With these things agreed upon, the coal question looms into being as the one of importance.

Testing the Coal. — Central station men depend upon coal as the foundation of their success. Its quality is as much a feature of profitable engineering as the conformity of the design of the apparatus to the purpose in view is so understood. That coal testing in the minds of many is a vague procedure leads us to interpolate in this brief word with the reader a record of a test made by the chemist of the city of Hartford on the coal utilized there for municipal purposes. There is little doubt that the reader will be well repaid for his perusal of the subject matter of the test, and though coal testing is not new, it is being improved each few years to a point harmonious with the needs of the hour. A business basis for all things is now generally accepted as the *modus operandi*. Central station service is one particularly dependent upon system for its success. System, however, cannot be expected to create its beneficial results unless it has the proper materials to deal with. Therefore with a test like this in view, no real excuse regarding coal can be reasonably made. To obtain the ordinary commercial analysis, or approximate analysis of coal, the procedure is as follows: A large sample, twenty or thirty pounds, of coal is taken from different parts of the pile. This is broken up finer and quartered down, and the operation repeated until a small sample of several ounces is obtained. This is ground to pass a 100-mesh sieve. The next operation is that of obtaining a test gram of the coal.

Weighing a Gram. — One gram of this is carefully weighed into a weighed platinum crucible and heated in a drying closet kept at a temperature of from 104 to 107 degrees centigrade for one hour. This temperature is sufficient to drive off the water without decomposing the coal. The crucible with the coal is then again weighed and the loss in weight equals the moisture in the original sample. It is then prepared for heat test.

Handling the Crucible. — The crucible is then tightly covered and heated for three and a half minutes over a Bunsen burner, and for the same length of time in addition over a blast lamp. It is then cooled and weighed and then culled: the volatile combustible matter; that is, the gases which cause the long flame in burning. The crucible is then heated uncovered over the Bunsen burner till all the carbon is burned and nothing but ashes remain. This sometimes requires several hours. It is then weighed and the weight of the empty crucible subtracted, gives the weight of ash per gram of sample. The weight of ash subtracted from the residue left after the volatile matter has been driven off, gives the percentage of fixed carbon.

British Thermal Unit. — A British Thermal Unit is defined as the amount of heat required to raise one pound of water one degree Fahrenheit. It is usually referred to as B. T. U. per pound of coal. For example, it is said, that for a given coal, B. T. U. 12,000 means that one pound of that coal would raise 12,000 pounds of water 1 degree Fahrenheit, or 6,000 pounds of water 2 degrees Fahrenheit, etc.

Analysis of Coal. — If a complete analysis, including the determination of oxygen, hydrogen, phosphorus, etc., is made, the thermal units may be calculated, but such an analysis would require far too much time and expense for ordinary purposes. The thermal units are also sometimes estimated from the results of an approximate analysis. By using a calorimeter, however, the thermal units are obtained directly by burning a weighed amount of coal in a steel cartridge surrounded by a weighed amount of water. A thermometer is inserted in the water and by reading the number of degrees through which the water has been raised, the result of the combustion is known.

Using the Paricalorimeter. — The method with the paricalorimeter is as follows: One-half gram of the finely ground sample is placed in the cartridge with one-half gram potassium chlorate and a measured amount of sodium peroxide. The cartridge is tightly closed and placed in 2,000 grams of water in the calorimeter. The thermometer is inserted in the water and the water is kept stirred by means of a small meter. When the temperature has become constant, a small piece of red-hot wire is dropped into the cartridge through a spring valve provided for the purpose. The coal is ignited and burns completely, the oxygen for combustion being supplied by the sodium peroxide and potassium chlorate. The thermometer is watched and the maximum temperature which is reached in about five minutes is noted.

Getting the B. T. U. per Pound. — The initial temperature plus a correction of about .02 degrees for the iron wire plus about .09 degrees for the chemicals is subtracted from the maximum and the gain obtained. If the room is much colder than the temperature of the water a further correction is added to compensate for the heat loss by radiation. This amount is found by noting the fall of temperature, after the maximum is reached, for five minutes, and adding the average amount per minute for each minute required for the water to reach the highest point. The resulting rise in temperature is generally about 4 degrees Fahrenheit for one-half gram of ordinary coal. This is multiplied by 3,117, which is the factor determined by the manufacturers of the calorimeter, and includes the 2,000 grams of water plus the heat capacity of the steel cartridge, and the chemicals used. The result of this multiplication gives B. T. U. per pound.

Getting at the Sulphur. — To determine the sulphur, the residue in the calorimeter cartridge is dissolved in water. The sulphur will now be present in the solution as soluble sodium sulphate; the solution is acidified with hydrochloric acid, boiled and a solution of barium chloride is added to precipitate insoluble barium sulphate; this is boiled and then allowed to stand until the precipitation is thoroughly settled. If possible it is better to let it stand over night. It is then filtered through filter paper, washed on the filter, and the paper placed in a weighed platinum crucible and heated until the paper is completely burned. The crucible plus barium sulphate is then weighed, and the weight of barium sulphate multiplied by .1373 equals the weight of sulphur in one-half gram of coal. If a calorimeter is not used, the coal must be mixed with the chemicals and oxidized in a crucible, after which it is dissolved out and proceeded with as stated.

The conditions of the test are such that the calorific values are obtained as well as the products. Calorific values, of course, are what we are looking for, and the extent to which they appear in a sample of coal is the measure of its value. After all it is a simple matter and one that if attended to well repays the experiment. Large central stations equipped with an analytical department can save considerable money if their business is sufficiently great to make this a feature of the system. If it pays a city to see that it gets good coal, why shouldn't it pay a central station? The answer to this is, that it does pay them, and is one of their objective points.

Avoiding Waste by Consuming Smoke. — The next problem is to get rid of the smoke, or to put it another way, to so completely consume the fuel that after good coal is selected it is not partly wasted by imperfect combustion. Thus we come to the question of smoke, the quality of the coal and the kind of chimney erected to dispose of it. The law found on the statute books of the State of Massachusetts is so written that "Dark smoke or dense gray smoke shall not be allowed to escape from any building or premises except locomotive engines, plants furnishing power for public service corporations or plants burning wood exclusively for more than six minutes in any one hour of the day or night." In the city of Pittsburgh people are forced to invest most of their surplus earnings in clean linen, through which the laundries have become large, important and indispensable concerns. In St. Louis and many other cities of the United States, the wealth of the community is derived from manufacturers in whose plants coal is freely burnt to turn the wheels of industry, and through which the money is made, the employer has his home and the employed theirs, and the city taxes are paid when due. This at least is one feature of interest with respect to the smoke problem worth mentioning.

In the report of the Committee on Fuel Supply of the Boston Chamber of Commerce, the following interesting facts came to light: "When the committee began its investigation of the smoke problem, a circular was sent to seventy-five cities in the United States, Canada and abroad, requesting a copy of their smoke ordinance, and information relative to the method of enforcement. The returns from these seventy-five cities showed the following: Thirty-five cities furnished a copy of their smoke ordinance and outlined the method of its enforcement. Twenty-two cities had no smoke ordinance. Eighteen did not reply. The report continues in an interesting manner as will be quoted very shortly, and institutes a comparison between Boston, New York and other cities as follows: "In seeking the most effective method of abating the smoke nuisance the committee has not only studied the laws of other cities, but has also sent representatives to investigate the effect thereof in some of these cities. The result of these investigations has convinced the committee that the absolute elimination of all smoke is practically impossible where soft coal is burned.

The committee found that even in New York, which is often cited as a city free from smoke, a considerable amount is *constantly being emitted* from the stacks of the public service corporations and other large users of coal. There is no doubt that the smoke nuisance is much worse in Boston than it is in New York, and much worse than it need be."

The result of the investigations were that of forcing the use of furnaces and coal-consuming plants. Smoke is fuel that is unconsumed. To consume carbon it must be exposed to the proper heat and flame. The heat and flame capable of that is supposed to proceed from a modern furnace or a plant having forced draft. The Bureau of Mines of the U. S. Government has investigated coal consumption and found a way of burning the coal completely and utilizing the heat of the gases, by increasing the path they take through the furnace of the boiler and reducing the tube diameter, for the purpose of getting the heat into more intimate contact with the metal. This is based upon efficiency and the best way of getting it.

The Well Designed Furnace. — The interesting feature of the smoke nuisance controversy seems to be that of conserving the coal supply and protecting the interests of the consumer. By making him use a well-designed furnace he is forced to save on coal; by saving in this manner the smoke nuisance is abated and two blades of grass are grown where formerly one grew before. The statement of the fact appears as follows: Aiming to abate, rather than suppress entirely the smoke nuisance, the Fuel Supply Committee has in its bill sought to provide a method whereby all coal users may be brought to the point of maximum economy in the use of their fuel gradually, allowing consumers three years in which to bring themselves within the final provision of the act. At the end of three years' time, if a consumer is burning a certain amount of coal intelligently, and in reasonably well-designed furnaces, he will in all probability be getting the most out of his fuel, and the public in turn will have just cause for complaint. Thus a compulsory, ethical, municipal, scientific and economic system, are the means by which the many are served, the few trying to be are benefited, and the public is pleased. The smoke nuisance carries its moral and all central station managers must beware. If your chimneys smoke, you will be forced to make money by the practise of new methods of economy. Efficiency is the objective point in this after all.

Scientific Management of Central Stations.— We are so used to being impressed by the large figures expressing the value of our manufactured goods that we are prepared to believe that extension is almost unlimited and that success in manufacture depends upon the gross output of sales. The small shop has been replaced by the large plant, and the partnership by the great corporation. The size of the plant and the magnitude of the undertaking is the cause of our interest in it. We want to be told of the amount of the work being done, but are little concerned about the efficiency with which it is being done. Not until the hearing before the Interstate Commerce Commission on the proposed advance in freight rates, held in Washington last winter, was this third dimension of industry brought forcibly to the attention of the public. It was there stated that one million dollars a day, represents the total inefficiency of the railroads of this country. There is but one cure for inefficiency. That is scientific management. The management of a complex industrial organization is a science. Not unsystematized management, but scientific management will secure efficiency. Efficiency is the test of successful management. In the case of a manufacturing plant as in the case of a steam engine, the output expressed in appropriate units, divided by the output expressed in the same units represent efficiency. From a theoretical point of view the ground seems to be very well covered, but the theory or principle must be sufficiently extended to make its application practical. For it is evident that cases arise numerous and varied enough to call for more than superficial generalization to arrive at correct methods and correct results. In the case of the central station, it is necessary to look deeply into the problem of the generation of electricity, in order to arrive at a conclusion sufficiently clear to be both valuable and practical. Scientific or systematized management of central stations is the basis of economy, success and permanency. Permanency is founded upon the community's good will.

To get it, it is necessary to give what is demanded and required.

To conclude, the following remarks are of interest: "In organizing an efficiency department on the staff of the general manager, it is recognized that the general manager, and the men in line under him, are unable to give the necessary time to the planning. That is the work of a staff under a chief, who is responsible to the general manager. The staff is in closest touch with the management and anything that needs executive action can be brought to the attention of the management. It is an easy matter for the management to attend to the matter through the line. Without such an arrangement it is not an easy matter for irregularities, abuses and losses to come to the attention of the management so that the responsibility may be fixed and the matter attended to properly."

CHAPTER V

COSTS AND THEIR RELATION TO CHARGES AND PURCHASING POWER

What Is Meant by Business. — A dictionary definition is to the effect that business is "Any particular occupation or employment engaged in for livelihood or gain." This is distinguished from trade by the statement that the latter is specifically an "Act or business of exchanging commodities by barter or purchase." Hence, the making of a living or a profit is one's business. Trade, however, is an act implying exchange. In a broad sense, a business is an institution which relinquishes something for money or its equivalent. Whether the institution be systematized or not has little bearing on the question. The act of exchange, seemingly generic, is included in the main proposition. Business is generic; trade is specific. One is the science, the system, perhaps. The other is a mere physical exchange, provided for and demanded by the process. At one end of the process is the thing to be traded in; at the other end is the consumer of it. Between the two are the various agencies, human or non-human, through which the traffic is directly or indirectly conducted. The effect of passing onward in this manner induces charges, either due to the need of the human agencies being paid or due to the investment in and deterioration of the non-human elements. Whatever these channels are through which the thing passes, it is evident that they and the system of which they form part, induce costs, which must be paid by those supplied with it.

What Is Meant by Cost? — The idea upon which cost is based is the tax upon trade. It is a feature of what is called "the profit system" and implies charges beyond fundamentally intrinsic values. As categorically defined, cost is "the amount paid, charged, or engaged to be paid for anything bought or taken in barter." Another form of definition is "To require to be given, expended, or laid out, as in barter, purchase, acquisition, etc." This being the generally accepted English idea of cost, it is instructive and interesting to see what phases it assumes under different conditions in business. These types of cost, however different they may seem, are still costs. Common logic demands that they be understood, defined, and traced to their related causes. Therefore, it may be assumed, that the causes, one or many, capable of classification along broad lines, are those to which costs of all kinds must be related. For instance, one cause of certain costs would be the particular character of the business. Another cause of other costs, might not only be the business, but the particular kind of customer. Hence, it is fairly evident that there are collective costs, common to the institution giving rise to them. There are also individual costs, distinct from those regarded as collective, increased and diminished according to the extent of the business, or what might otherwise be very aptly called "the traffic." The costs that are general, equally apportioned, the result of normal conditions of business, such costs as cannot be readily discovered whether a little more or a little less business is done, are *joint costs*. These may be distinguished from another kind of costs caused by increased pressure on the system, which pressure cannot other than cause an unusual strain, or be the reason for a different distribution of the operating forces. Costs such as these are not of the character typified as joint. The fact that this strain is generally a continued one, and causes a variation from the otherwise distributed form of it, invites a cost that is characterized as *increment*. With this broad interpretation of costs, it may be easier to classify them when they appear, because of their obvious relationship to conditions, if not causes, that vary the distribution of the operating force in business.

Controlling Conditions. — As civilization has produced business, it differs in certain respects from its earlier and more primitive form. To-day, money or gold is sought as the great objective because it symbolizes and is, purchasing power. In the days of the dawn of civilization, barter or trade was conducted for the securance of equipment or food. The equipment was one of arms and thus represented, as gold does to-day, power. With the advance of civilization and the merging of various units of value into the one or two common standards, gold and silver, the system changed. Its outward and primitive simplicity was affected by the new *regime* and became transformed into one of greater complexity. Consequently, it became necessary to analyze the influences or conditions acting upon a transaction, in order to interpret the charges resulting from it. For instance, two phases of business, one the apparent antithesis of the other might arise; the article, commodity or thing causing the transaction, may suffer from the effects of a form of competition that has neither check nor limits; on the other hand, it may represent a protected form of sale, so well protected in fact, that it constitutes a higher of the two rates given on the name plate or in Tables I–V, and reduce the current in several steps, avoiding gassing and high temperature, until the finishing rate has been reached. Continue the charge at this rate until the voltage and specific gravity have risen to maximum values. At this point the cells will be gassing freely. It is better to stop the regular charge too soon than to overcharge. It is permissible to begin the charge at a higher rate, but care must be exercised to reduce the current should the cells gas or the temperature rise above the allowable limit.

Where any device or means is used in regulating the charge, especially as to the length of time, it should be adjusted so that a uniform gassing at the finishing rate, indicating the end of a regular charge, will be produced. This amount varies somewhat but is between five and fifteen per cent. more than the number of ampere-hours taken from the battery on the preceding discharge. This statement applies to ampere-hour meters, time clocks and rectifiers fitted with an automatic attachment.

Uncontrolled Competition. — Conditions which were imposed upon business without limit or control, had the effect of holding prices down to their lowest. Such competition left little or no margin for profit. A rise in price would be driven down by that price being equalled or reduced by others. To reduce prices below cost would mean destruction in the end. Competition thus called for every device to gain an advantage. It exhibited itself as solicitation and advertising, by reducing quality and value, by reducing the cost of production or manufacturing, or by a reduction in wages. When thus acting, the weaker in this cosmic struggle for existence naturally fail. Competition, therefore, operates in business life, as the laws of Nature and environment upon the physical form and habits, in the animal world. The fittest for those conditions survive, the others perish. If these influences act on the body politic, to increase its *purchasing power* as a whole, a general benefit results. Should examination prove that it diminishes the general purchasing power, then such parts of competition as act this way should be suppressed, as evidently injurious and opposed to public welfare. An axiom that could be deduced from a survey of the phenomenon of competition would be as follows: Business processes which reduce the purchasing power of a community are opposed to public welfare. In this manner it might be possible to reduce what would otherwise be unusual costs pertaining to an article.

Competition Eliminated. — A business which is not forced to exist by its unusual efficiency in soliciting, in advertising, or other forms of competition, may be approved of by the public, given a special grant, and thus, as it were, with competition eliminated, carry on its processes profitably. A public service corporation is exposed to certain forms of competition which affect its costs. The postal system of the United States, however, has no real competition, and is controlled by public opinion. A central station supplying energy to a city is forced to solicit and to advertise and to keep a sharp eye on the cost of production. Competition is passive, not active, because it acts in the form of three stimulating forces arising from public opinion. One of these is crystallized in the press. The reiteration of complaints here generally lead to an investigation, from which arises public service commissions or judicial actions. In other words, public opinion, the courts or commissions are the checks which regulate the processes carried out by public service agencies unexposed in the ordinary sense to competition. But the situation resulting from this is the same as though competition was fully operating, with the difference that *the purchasing power of the community* is not so reduced. Hence, a monopoly exposed to the three regulative influences of public opinion, commissions and court action is not actually, but is practically subjected to the equivalent of competition. It is in competition with the public. No matter what its costs of production, public opinion governs its charges of rates to a marked degree. In present communities monopolies are impossible in an unrestricted sense. The restraining force operates in a similar manner to competition in fixing prices. The difference is that with uncontrolled competition one can raise their prices if they wish. In public service corporations this is impossible because it is illegal.

The Principle Governing Costs. — The modern system of regulating rates is one which produces two general results. The first is that of fixing prices the same as if uncontrolled competition was acting. The second is that of restraining profits so that only an average banking return is had from the investment. Consequently, public opinion or the public itself becomes a silent partner in hypothesis, because it engages to supply the custom, demanding as its share a dividend in the way of reduced rates. To carry out the public will, the costs of doing business must be carefully scrutinized. Whatever charges are made must be in relation to the costs and the return on the investment. The return on the investment is the income to be supplied to stockholders. The processes of doing business must be based upon this idea. As various classes of business will be transacted, the charges for them must be apportioned to supply the earnings required after costs are deducted. Hence the principle governing costs should be one that makes it a function of the dividend. The larger the amount of this stock held by the public, the greater must be the aggregate earnings. Too much stock otherwise would mean a low dividend; too little stock a high dividend. Consequently, the dividend rate, the percentage earned by the stock, is no criterion of the rate of the earnings. The proper basis is the total investment, much of which may not appear in the schedule of intrinsic values. An unusual percentage of profit shown with respect to all elements, visible and invisible, that constitute the investment, might prove a reason for a change in rates. The tendency to judge by the stock quotations is unfair as an index of the correct relationship of profit to investment. The total cost of doing business, the extent of the total investment and the total amount earned, are the three sets of figures affording a final conclusion in this respect. The costs, then bearing upon the part of the investment, or the class of custom producing them, are the main feature. Consequently, whether joint, collective; or increment, individual or class costs; the principle governing them should be their relationship to the total earnings, the charges as a whole and the earnings on the investment.

The Theory of Class Rates. — The placing of costs lies at the foundation of class rates. These costs must be placed with respect to their causes and the group or class to which they belong. For instance, if investigation shows that one set of costs are caused by a special class of customers, it is evidently wiser to group them than to let them be treated at haphazard. The electric, light, heat and power business is a case in point. All of the customers are the cause of a certain usual expense, denominated a joint cost. But if in addition to a usual expense there is an unusual one, then it must be inherent in that class of customers, added to the usual expense by service to him, or subtracted by his disconnection from the line. The idea of this latter brings into existence what is called an increment cost; an increment added to the regular, general and to-have-been-expected cost. The distinction to be drawn, therefore, is that between an increment and a joint cost. The joint costs are those that aggregate the larger portion of the costs of the business process. Regarding the business process as one involving the transaction from its inception to its end, from the generation of electricity to its consumption, everything transpiring in connection with it would be included. The total of the joint costs can thus be estimated and perhaps some method found of charging for them in an equitable manner. For instance, a distinction can be drawn, such as by the government, between the various classes of articles sent by post. Other concerns do this as well; the telephone company having classified its business into types calling for a difference in rates. In railroad service, there is a difference between passenger, freight and express rates. And this difference, to a degree, is exhibited by other types of business as well. Consequently, there is nothing unusual in a central station corporation carrying out the same practise. It is something the public is familiar with, and, in a sense, expects. Therefore, the great question is not the reason why such differences in rates are made, but how they shall be made? One point at least is certain, and that is that the rates must be such as will please the public, without undue agitation in any shape or form. One of the fallacies about rates has been that they could be charged irrespective of any other idea than that of profit. This is now considered archaic. The modern way of considering charges is to make them, as if a strong and active competitor existed, even if he did not. Another valuable theory carried out in practise is that every sort of service has a definite *value* to the consumer. Requiring that this value be paid, is the essential point of it all.

Getting More Business Through Rates. — A rate established for a class or established for an individual must be based upon the real values. When a class of customers are thus charged, it must be with a foreview of the future, as well as a knowledge of the present. The estimates must be based upon an increase in the bulk of the business, when the class is greatly augmented. With a single large customer, or one of a class of heavy consumers, one idea governing the transaction would be the amount of his tax to the common expense, the joint costs. After all, the joint costs are the important item in the bill of expenses. A large consumer would be considered from three points of view: the total consumption of power, the extent of his demand, and his size. In such an instance the idea would be to have customers of this class contribute as heavily as possible to the joint costs. By this means equilibrium is established, the larger ones, those of size, helping the smaller ones, those of number. A formula, supposed to express this proposition, called the *demand basis*, involves these three items as follows:

Costs = number of customers $\times$ a + kilowatt hours $\times$ b + kilowatts of demand $\times$ c.

This expression embraces certain conditions, but there are complexities in the system and service which would make it difficult to always arrive at correct coefficients. There are certain stages of development, of growth, in a central station of size, such that at one phase of the growth the costs are *d*, and at another stage the costs are *e*, etc. Customers must be charged justly or the rates will become unpopular and lead to unrest, distrust and legislative retaliation. Rates ought to have the effect of getting business, particularly when adjusted with the idea of equity in view. The effort made in this respect should be controlled by the two points of view: first, to charge so as to yield a fair percentage of profit in general; second, to preserve a popular rate. If the experts in charge of the rate-making in any corporation fail in this, it is evident that they are intellectually, financially and technically unfitted for the work and ought to be rapidly removed. Changed rates ought to get more business, and should be such as to prevent legislative action if ethically and popularly made. A simple rule to follow is one based upon elementary logic: they either produce too little, too much, or just enough. The silence of the public is a testimonial to the last. The activity or elimination of the company will prove that it charges too little. By knowing the cost per capita, the average cost, the rates can be safely and accurately determined. By seeing that new business, new customers, aid in averaging the joint costs, they will be reduced per unit through such a distribution, and may be led to a reduction in rates. Such a reduction may again increase the new business, calling for another redistribution of costs and a consequent reduction in rates. Therefore, it is evident that new business, the better averaging of costs and reduced rates are mathematically related.

The Futility of Unethical Rates. — After all, the nation is simply a large community, consisting of many families, bound together by what seem to be artificial restraints, but which experience and custom have made necessary for the preservation of good order. In other words, the legislative and executive departments of the government are fundamentally interested in the general welfare, not in a philanthropic sense, but protectively. The growth of modern ideas, filtering through the public mind is leading the nation to another point of view. It is seizing hold of the idea that whatever is opposed to public policy is hostile to law and order. Its opinions on the subject of public policy have deepened and broadened. It has begun to draw a line of distinction between what is ethical or non-ethical, not only generally, but specifically. All forms of business are now being scrutinized from a higher point of view. The right to make a profit is not considered inalienable if it causes injury or injustice to others. Large business has fallen under this ban, and probably small business will some day follow. The law is now being so framed that it is pronouncedly ethical. Consequently, it is futile for any organization of size to attempt to be free in rate making, particularly those operating in the class known as public service corporations.

Reason and equity are the ruling forces, backed by public sentiment. This is partly because of the fact that the editors' column has become a forum, a public platform, more closely attended and carefully listened to than the pulpit. The force gaining strength in politics, legislatures and large business organizations is ethical. This is but a reflection of the general mind, and these conclusions are becoming more emphasized in all forms of civic duty. The idea is slowly but surely gaining ground among political economists, and the intelligent public, that *the charges* made for things, all things, and the money to buy these things, *the purchasing power*, must be kept in certain relations to each other. The rates established by one industry or the charges made by another cannot be the result of careless thinking. Even ordinary commercial considerations will not do to-day. They must be based upon scientific, if not ethical, ideals. The element that must be preserved in the nation is its purchasing power, as a whole. That which diminishes it, due to direct human agency, is opposed to public welfare. That which increases it, is an aid to general prosperity. Rates or charges, not specifically, but generally, ought to be based upon this broad idea. They should be designed to increase the purchasing power of the community, not to diminish it. And the way to accomplish this is to hold the profit down to its lowest reasonable minimum. The two forces, therefore, that determine prosperity, activity in business, the circulation of capital, are on the one hand the prices of things; on the other hand, the purchasing power, the ability to buy. A new interpretation of the regulation of rates, therefore, is the preservation of the purchasing power of the public. This seems to be a matter of Federal concern. Federal control of the health of the nation, a recently proposed idea, is not more important than the preservation of its purchasing power. When competition greatly reduces this power, or other destructive influences, the public welfare is being affected. This principle is basic as far as existence is concerned, and must be of vital importance in the arranging of rates, whether for electricity or other agencies or goods representing indispensable necessities. Consequently, rates must be made to meet these new conditions in society, the strongest force of which is an augmented sense of justice.

CHAPTER VI

HOW CENTRAL STATIONS GET BUSINESS

Increasing the Connected Load. — The necessity for increasing the connected load is due to several conditions imposed upon the organization as a whole. One is that of the wear and tear of the equipment. Another is that of competition. A third might be the need of keeping pace with a growing community whose requirements if not acutely felt, must be developed through the forces of solicitation and publicity. Another is the fact that every decade or so the system changes through the natural forces of evolution, so that what was once useful and new becomes obsolete and risky. Therefore, it may be said that depreciation and an improving system, are the two elements which co-operate to keep a plant modern and efficient. Summing up the conditions which call for a campaign leading to increased business of a new character we have: 1st. The expense due to depreciation, and the cost rolled up each hour of every day due to taxes and interest on the investment. 2nd. The expense naturally arising through the conflict of competition, without which struggle, modernness cannot be preserved. 3rd. The expense due to solicitation and publicity, these two being the active means by which competition is effectively controlled. The connected load must be increased for other reasons as well. In all businesses there is a loss due to business liabilities. The fact that 95 out of 100 men fail is due to their own inability to discover in time the road to success. And if a business is on the high-road to success, it is necessary to make provision for unexpected as well as expected conditions. There is a leakage in all concerns, some of which can and some of which cannot be stopped. For instance, of all the business a concern transacts, a certain amount is lost. On the other hand concerns intending well get into difficulties and fail. Other concerns do not fail but go out of business, liquidate, which means lost business to the station. Also customers give up, move away or try experiments of their own in lighting. Non-payment removes another lot and so on until a certain percentage is lost. To meet all this, whatever it may be, it is necessary to have new and promising business come in to allow for this loss. The connected load is the measure of the amount of business done day and night. But the business must be made to increase through broad and astute management, so that all the drainage is compensated for by new blood flowing in healthy channels.

Business Getting. — If one were asked the secret of business getting, the answer would be, order and system. It would naturally be a campaign of soliciting and advertising. Other commodities than electricity might use modified forms of action, but with electricity as the thing to be sold, the need of the press, of circulars, of bulletins and of demonstrations is enforced because electricity is a comparatively new element to mankind and its various applications and advantages are yet to be learned. "There is no system," as one writer observes, "of soliciting light and power which can be adopted universally; each and every community is a separate and distinct case, and for successful results demands as careful a diagnosis as would an individual at the hands of a skilled practitioner." In the larger cities, the solicitation of light and power is given the entire time and attention of the head of the "Publicity and Soliciting Departments" or by what other name the department may be known. Advertising by electric light companies was, until a few years ago, an unknown proposition, but the electrical fraternity have awakened to the fact that this is an advertising age, and electric lighting is as susceptible to the effects of advertising as "Mr. Beecham's Pills" or "Mr. Stickum's Corn Plaster." The methods of business getting as followed in a general way by the central stations of the United States at least can be tabulated for inspection in the following manner: 1st. A soliciting force, whose work is that of getting the business from such districts as are portioned out to them individually and collectively. 2nd. The use of mailing lists divided up to suit the class of business such as lists for motors, for residential lighting, for windows, etc. In connection with this, it has been found best to use a card-index system or such forms of mailing lists as will avoid duplicates in sending. 3rd. The use of a system which, while it keeps the solicitor clear about his moves and customers does not take up too much time to follow. 4th. Private company printing plants, for the purpose of getting out such printed and illustrated matter as will appeal to public taste. 5th. Monthly publications whose appearance in business offices and homes at regular monthly intervals acts as a stimulus to business. The more useful and practical the information, the more they are looked forward to and depended upon when necessity arises for reference. 6th. Illuminated sign boards are employed in prominent places, the signs possessing exceptional features to attract attention to the fact that the central station supplies light, heat and power. This is often accomplished by means of signs having moving parts to them. 7th. By means of booklets which reach the public through the mails and apprise them of the advantages of electric light, heat and power. The use of such literature also leads to other forms of publications, some of them very artistic, but sticking consistently to the theme of business. It may be noted in connection with this subject that unless the mailing list be kept fresh and up-to-date, the booklets might as well be burnt up as distributed without rhyme or reason. In small towns this is more easily possible than in large ones, and therefore a well written and well printed booklet has a business getting capacity that is remarkable if the mailing of them is wise. Responses from booklets have been calculated in percentages by some statisticians, figures of from 2 to 5 per cent. being given for returns.

Missionary and Educational Work. — In connection with the development of business, it is easy to perceive, that people must first become acquainted with the general purpose of the agent before becoming familiar with the details of the plan proposed. For this reason the getting of business is partly dependent upon the agent or advance guard of the company and then upon the powers of demonstration and explanation of the technical man. As one writer puts it: "The managers of lighting plants should realize that for the development and expansion of their business, much missionary and educational work must be done in connection with familiarizing the general public with the flexibility of the electric service. It is not a broad statement to say that to-day not one householder out of every ten has any conception of the development of the numerous electrical domestic utilities." This last statement may be challenged, but in a general way millions of people who have heard, at least have not seen an ocular demonstration of such devices.

Ocular Demonstration of Devices in Use. — The initiative in business is the only way to get it. For this reason successes have been noted in each particular line of it. These successes were the result of those founding that particular business adopting an original idea. For instance, in the campaign for education and enlightenment, the central stations doing the early missionary work are those who got the business. The men alive to this condition, to the fact that descriptions are fine as introducers, but demonstrations are better as business getters, got what business was originally to be had and built the foundation of such industries. The articles must be shown in practical use, the cost or operation must be proven to them, the reliability of them must be guaranteed and then the purchaser draws his own natural conclusions. One of the best means of securing business and confidence at the same time is that of permitting the articles to go out, if electric heating or cooking utensils, with the proviso, that unless perfectly satisfactory as represented, no obligations will be held. The public was once exceedingly timid of all that pertained to electrical apparatus, even afraid to touch it. Since so much of it has been made fool-proof, it handles it now as though such devices were of ordinary character without any special significance whatsoever.

Pushing Heating and Cooking Devices. — One writer is exceedingly confident that heating devices represent the salvation of the central station as a business getter. He states as follows: "In the opinion of the writer there is no channel which gives the promise to the central station of as much additional business as that involved through pushing the entire line of heating units. The writer has in mind at this moment a case within the state wherein a large hotel is serving all griddle cakes, toasts, chops and steaks from electric grids. In this instance the consumption is about 2000 K.W. hours per month, 85 per cent. of this consumption is during other than the peak load interval. The rate is five cents, we doubt if there is, everything being considered, a better piece of business in the state. The advertising which the company has secured in connection with this installation has influenced many sales and will no doubt influence many more." The idea in this case was to add to the day-load, not that which runs into the peak. Due to the fact, that in central stations it has been the case to have 75 per cent. of the investment idle during the day, the necessity for having it at work is obvious from every point of view.

Working Up the Motor Load. — The great objective of the agent's selling power is factory business. Factory business is one of the best arguments to prove that electric power is a necessity in industry. The idea that electricity can be produced more cheaply by isolated than central station plants is one that can only be disproved by facts to the contrary. The central station is put into the position of finding it necessary with its system, experience and investment, to put out electric power at a lower price than it can be privately produced. Sugar-refining, gas-making or similar processes do not suffer from private competition, yet the field in a sense is just as free as that of electric lighting or power producing. In large factories, unless the circumstances are exceptional, it pays to use central station power, because the generation of electricity is a business in itself, one that merchants are wise to regard with suspicion. If a man is in a paying business, he can discover the limitations of it, the various by-paths to avoid. Making money in business is due to a distinct view of the only way it can be made. Experiments in other directions are tempting but dangerous. Therefore the solicitors of power business need not fear difficulty in getting it, because it is the duty of the central station management to meet competition of this kind successfully. The working up of the motor-load therefore, to increase the day-business is only to be expected. The terms of such contracts may often be very close, but it is evident that on the whole, however close the aggregate, there will be enough profit to swell the day-load and aid the investment.

Encouraging Ice Making. — The management of the central station may be able to use the plant up to a fuller capacity by means of ice machinery. A million dollar plant paying 6 per cent. because of its use during 16 hours of the day, could, by being used the other 8 hours, increase the income 50 per cent. This would mean, on an equal basis, not only $60,000 a year, but $30,000 more, or $90,000 in total. This is equivalent to the erection of another plant of half the size, or the extension of the plant about 50 per cent. With an ice plant operated by electricity, the ice could be stored during the day as the new batch is being made. In the summer the storage would be a fund of cash to draw upon, in the shape of ice, capable of quick realization. If hygienic ice plants make money, it can also be made by additions of this kind to the general equipment. A busy central station could not afford to engage in a new enterprise of this kind, but one in which the day-load hangs fire can do so through necessity. Many plants report good results from this departure, but the large city plant would need a storage plant as well. This, in a place of crowded buildings and high rents would not pay. But in many small towns where storage would be cheap, ice would be easier to handle during fall and winter months. When held until the spring and summer there is money in it. Favorable reports on this score have been made, and as a money maker there is something in it. It may seem incongruous to obtain heat and cold from the same concern, but the ability to do it is a good sign. As a business proposition within limitations it is all right and has given greater use to the investment than was otherwise possible at the time.

Display Rooms. — The psychology of display rooms has its effect in increased business. Central stations now have a fixed practise in this respect. The display or demonstration departments are handsome and effective. The cost of advertising and exploitation is, in a sense, much higher than that of supporting fine rooms, well decorated and designed to invite business. As a writer puts it. "A window full of handsome lamps, attractive cooking utensils, or other electrical utilities, will catch the eye of many passers-by, inquiries will result, and if same are properly handled, new business secured. Many lighting companies hold that they can well afford to sell portables, heating units and such devices at actual cost, and spend some money for advertising as well. A manager recently told me that it cost his company $3.00 apiece to sell fifty handsome portables last Christmas. These portables were, many of them, given as presents; a number of them went into homes which had no electric wiring, and the company secured six desirable customers through the sale of these lamps." Aside from all this, however, the display room in charge of technically intelligent and fluent agents means a money maker in the end. They pay well, the more inviting and interesting they are. Well trained girls can readily conduct them.

The Methods That Pay Best. — The methods that pay are the ones to use; but who discovers them? They are the footsteps of the successful man. If he hits upon them at the start he is a success. Otherwise he may fail or drag along in a mediocre way. As the writer again states, "After all has been said, the method of securing additional light and power business narrows itself down to any method which appeals to us as being sound from a business standpoint, and profitable from an income standpoint, whether there is an established precedent of the method or not." This last is the inviting and valuable phrase, "whether there is an established precedent of the method or not." Too many are timid and wish a guide. The few enterprising and original successes strike out for themselves. He continues as follows: "Free signs, controlled flat rates, free lamp renewals, and many other forms of attractive service are more or less familiar schemes. The most attractive proposition of the above number is the flat rate sign scheme, whereby the customer agrees by contract to pay the central station a stipulated sum per week or month, for a term of one or two years, this covering the cost of the sign and the service; the monthly or weekly payments being based on the number of hours per night the sign is to be in circuit. Company's patrolman has the key to the switch, and the company is thus in control of the stituation. The Chicago Edison Company was very successful in this line, having in operation many thousands of signs, and the management states that the sign business is a profitable feature."

Individuality of the Intelligent Solicitor. — Of all methods known none can be compared with the efforts of an intelligent solicitor. The solicitor must be backed up by his company with good advertising matter, and clothed with that dignity which the company's representative must have to succeed. No company should be so aggressive in its advertising and soliciting as to become offensive. The soliciting art has been the object of much unkindly feeling on the part of the general public through the offensive tactics of book peddlers and life insurance agents. Consequently, the individuality of the intelligent solicitor is the important element in the outside activities of the company. The attitude of the public, its patience, and willingness to accept as true the statements of the main office are largely the results of its confidence in the company, largely derived from the first personal experience obtained. In all successful businesses good will is the most valuable asset. It is obtained through the personalities of men who are pleasant, obliging, honorable and have the happy faculty of being remembered. The central station manager must have the talent to select such men for all important positions. The *personnel* of the company must be built up and preserved in an atmosphere of this kind, particularly a public service corporation. Otherwise some day a rather bilious-minded employee will assume enough destructive dignity and offensiveness to put a hole in some valuable business. The repetition of this in the course of time means a growing tension between the company and the public. The outcome is the loss of that happy element called influence and the breaking out into print of some aggrieved patrons in the columns of hostile newspapers. The rest follows, as a matter of course, with its disagreeable features. Intelligent, courteous and capable men are the only solution. These will give the company's name a welcome and this is the only means of turning electricity successfully into money.

CHAPTER VII

"NEW BUSINESS" FOR CENTRAL STATIONS

Nature of the "Charges for New Business."— Obtaining new business is the most interesting part of the work done in the commercial department of any concern. Firms or corporations, roughly speaking, either produce or store, and sell. Producing, implies a plant of some kind. Selling, involves the idea of a selling corps. Where goods are stored, the force is that competent to care for a warehouse, or the addendum to a commission business handling car-loads of country products. Producing and selling are the essential components of a central station, or electric light, heat and power establishment. Producing, is a technical, scientific and expert phase of the work done in the station or electric light plant. Selling, is the commercial aspect it assumes to the merchant. The costs or charges involved in selling, or getting new business, are just as important in the electricity-generating-plants, as in those producing textiles, hardware or foods.

Heads of Departments Getting "New Business."— Employees getting "New Business" and those engaged in campaigns to develop public interest in a concern, are both included in this category. Two kinds of activity appear here: that of those helping to add to the sale of the product along its customary channels, and that of those discovering new channels and forcing trade there. In addition to these are charges or costs pertaining to those acting directly as agents, and to those closing contracts bringing new business. Consequently the charges for "New Business" would include the salaries of the heads of departments promoting and developing electrical consumption; also that of the salaries or portions of the salaries of managers and clerks whose work consists in developing "New Business" by means of agencies or contracts. According to the sub-committee of the National Electric Light Association, whose labor in preparing a pamphlet on the "Accounting Section" of the electric light, heat, and power industry, has placed the matter in a classic light, the following is true regarding "New Business": "Charge to this account the salaries of the heads of the department maintained for the promotion or development of electrical consumption, including that portion of the salaries of the management and clerks in agency and contract departments assignable to new business." This differentiation of the routine from the creative parts of the business is just as necessary as the distinction made between the purely clerical and technical phases of the business. Routine work is necessary to hold the organization together, in fact, it is the organization. But the growth of the concern and its gain in new and healthy blood depends entirely upon those engaged with the responsibility of finding ways and means of actually adding

"New Business" to the books of a profitable nature.

Advantage of Knowing "Costs." — It seems quite obvious that a commercial law could be framed like the following: "Money spent in getting 'New Business' is invested in the business." So often a merchant or manufacturer is heard to say, "I lost such and such an amount trying to get some new business," whereas the new business was there, but too much was spent in getting it. Consequently there is an advantage in knowing costs. Unless the value of labor is known, an employer can waste a fortune in wages without results that pay. Business men waste or lose money through lack of logic and experience. But the money spent in paying for an advantage is not lost. All advantages are not immediately resolvable into money. In the industry of supplying electricity to the public certain advantages have to be gained of a permanent character. These are the points of support to the organization. For instance: the advantage of owning ground, owning the building containing the plant, owning certain franchises or rights-of-way, having modern machinery, having good organization, having efficient and intelligent employees and having invested money in securing a good *personnel*. All such costs are definite. Part of them are for the fixed and visible element of the industry. Another part — invisible — were spent in organization, progress outside in getting business, altogether, in establishing the concern on its feet. "Going Value" is one title for part of this, but the cost or charges for "New Business" is another and may include many items. It is therefore wise to establish a "New Business Department" and keep careful note of its costs. A list of the items essentially comprising it are given in the sub-divisions of "New Business."

Sub-Division of a New Business Department. — A new business department will include canvassers or agents soliciting new business or contracts, advertising men, men responsible for promotion ideas, and who see that they are crystallized. As Emerson has stated in one of his incomparable essays: "There are thinkers, sayers and doers." And this is what is found in the correct *personnel* of a thriving, because well organized, central station, or other business. The head of the department, responsible for its thinking; the aides at his command, who say and do what he requires. Under the active head of the department "maintained for the promotion or development of electrical consumption" would be the following list of men, their work, and such items as lead to business:

1. Clerks in agency and contract departments, all or part of which, can be regarded as relating directly to new business.

2. Miscellaneous supplies and expense which would include office rent, all or part of that legitimately belonging to new business.

3. Soliciting, which would embrace all amounts paid out for the salary and expense of canvassers. This would not only be an expense for soliciting, but would include a cost for commissions, for the

preparation of estimates, for engineering advice and all leading to new business.

4. Advertising, under which head would be found printed publicity. The salary and expenses of an advertising manager and his clerks.

5. Promotion wiring, furnished without cost to induce new business. Sometimes such wiring is done as a charity or an exchange courtesy.

6. Promotion Signs and Devices, the cost of which is considered legitimate because it is sometimes a trial which brings new business.

According to these items, it is evident that canvassing, publicity, trial or promotion wiring, estimating and engineering advice are organic parts of the one system whose object is to gain new business. These sub-divisions will be separately considered.

The Art of Soliciting New Business. — There are three kinds of business to obtain: one is that of the city proper; another that of the suburban sections; the last, that of rural communities. In each of these fields of business there is a distinct difference in conditions. The city is already electrified, and cost is the great problem. This is mainly the cost of wiring or the inconvenience of the doing of it in old buildings, homes, occupied by conservative people. This is being swept away, however, in the tide of progress. Everyone in any large city in the United States admits the advantages and cheapness of electricity as a house agent. In suburban sections, settled by people of limited means, desirous of feeling the independence arising from having one's own roof over one's head, the addition of any costs is looked upon with disfavor. They wish to do many things themselves, paint their houses, repair them, add extensions and fight investments beneficial to others as they think. Only the homes already wired or easily wired succumb to the initiative of the canvasser. All new houses are built wired, the others are slow to respond. But with them all, the proof of an ultimate saving is the strong point. The real power of the fact only operates after the electricity is in service and they are accustomed to it. It is then impossible to have them give up the *comfort* of it. This is the key to the situation — comfort. The argument over costs is really only important when it is unduly emphasized. If the cost is much greater there is a reason for objecting, but the strength of the agent's position lies in his ability to show that drudgery is the lot of many women and its chief antagonist in the home is electricity. The value of a woman's labor added to inconvenience and fire risks in having flame in the house for domestic service, in contrast with the "touch of the button" idea, and reasonable cheapness as well as modernness, seems productive of interest. With the growth and spread of feminism, men will find it necessary to supply the home with labor-saving devices, in order to be just to his weaker kindred. It is inevitable that with the "New Freedom" will come all that pertains to it. In fact, the whole idea of freedom, aside from the justice of it, has been supported by arms, forms of invention, not the least of which are those entering the home, though of a more pacific quality. But they are there, and as a consequence, more time is given to man to think and solve the political problems of his destiny. Consequently machinery, labor-saving devices, inventions that mean convenience and take away the cruel and crude edge of drudgery must make their inevitable appeal to thinking people. In developing the art of soliciting new business, the agent must possess a broadness of view as well as a keen business sense in order to prove the need of his utility and its comparative cheapness. Clerks in agency and contract departments cannot be too well informed of the circumstances and science of social movements if they wish to succeed in impressing their personality upon the customer, the effect of which is not only educational and advantageous but it leads to sales.

Engineering Advice as a "New Business Getter."—Another feature of business getting is the fact that so much advice has to be given in the way of reasons why current or devices should be installed. In the life of a physician those who need advice pay for it simply because it is the custom and the application of it is personal. It is not necessary for him to solicit trade and force people to accept his opinions of their need of his services. With central stations and many contractors it is different. They have to give advice because it is the custom. This custom arose as the result of the newness and therefore the weakness of the electric light industry in the past.

It had to prove its usefulness in almost every case to be recognized and utilized. The gradual electrification of the United States is removing that impression, so that the consulting electrical engineer thrives to-day. But with the sale of electricity many problems arise, each different from the other. On account of this, contractors and central station managers have had peculiar work to do. They have had to give advice in many cases in order to get their business. Now, as this is a regular thing in many cases, it seems as though the advertised fact of a staff ready to give such advice for a nominal fee would lead to more business from those hesitating as to the best course to pursue, or having decided to install electrical appliances, do not know what choice to make or the most satisfactory step to take at once. A consumer's consulting bureau would act as a clinic for cases and help to establish relations of service apart from the mere business phase of the sale.

What Advertising Brings "New Business." — The natural answer to this would be that all advertising brings business. But emphasis is not laid on the amplified old business, but business which is germinal, new, full of possibilities and therefore associated with the future of the concern. This is the most important business any industry can get, for it represents the freshening of the life blood of trade. Consequently, it is necessary to know what form of advertising calling for public attention is most vital and comprehensive. Is it the public sign, the printed folder, exhibitions on a large scale, or promotion work, done to advertise good will and secure orders? The public exhibition of applications of electricity is the most interesting of all. Its difficulty lies in its limitations. Only a few comparatively can call of the millions that ought to see it. But even so, those arriving carry away the germinal idea, the intention or the wish to use electricity or its devices. Thus, the effect is psychological. In fact, that is salesmanship. It is the process of creating desire for a thing heretofore disregarded. The actual sale, important though it be, is an incident. The desire to buy is the great event. Planting this idea is not only salesmanship, but advertising. For advertising qualifies and insists, whereas salesmanship creates the consent, because of the wish. Thus, all advertising that excites interest apart from sales is basic. This is the new business getter. If the idea of a sale is paramount, the sale may fail. Therefore, the proper idea is that of creating interest and desire in all advertising that is creative. And concerns having experts will find that the better of two is the one in whom the art of instruction is best developed. This display itself is an instinct to explain and demonstrate. Thus, the idea of wanting it is born, and the sale follows, sooner or later. In this respect, new business getting calls for unique skill. The essential point in advertising is to select the best channel to follow, but this selection requires the best judgment to get the best results. This selection, in the case of electric lighting, should be some branch of it capable of much greater development through the implanting of new ideas. For instance, two fields of enormous extent are: electric cooking and heating in homes; and the introduction of electricity for lighting among the people of humble walks of life. The greater element in the population is not rich, nor even well-off, yet they as a mass are the greatest consumers we have. Were they all wired up, an enormous addition to the load would be visible. Did those who now use electricity, employ it for cooking and heating more extensively a large increase in current consumption would result.

The Psychology of Getting New Business. — Salesmen are born, not made, they say. Geniuses are born, not made, also. In a higher sense, a born salesman is a genius. For a genius automatically does the thing that makes him one. He sees how easy it is for him to do, whatever it is, and he does it. But all of them have been workers, the hardest, the most absorbed, the most self-sacrificing the world has ever seen. Their work is new, creative, productive, and of use to the great public. This is a point of common interest between the genius and the salesman: what they have the world must want, or they both cease to be either genius or salesman. Yet both have a certain trend of thought, the one to sell, the other to originate. But the salesman who steps out of the beaten track and sells above his fellows, by the force of his personality, energy, intelligence and confidence, is an unusual man. He has enthusiasm, power, and an instinct that guides him to his goal. This is a native quality developed by practise, by its exercise and success. And an analysis of the psychology of selling is in many respects the secret of business success. Consequently, the creator of a gigantic organization, a business, is a disguised salesman, an original-minded man who knows how to plan enormous sales, or the converse production. His genius is thus on a par with that of those of a more personally intimate character. It is not music or art or literature, but a form of invention, a power over production and distribution.

The secret of selling is threefold, as far as the purchaser is concerned. To sell him properly there should be in existence the following: necessity, convenience or advantage, and gain. The first is a factor that takes from the sale its lustre. So hard a need as this implies consumption. They would have purchased themselves had no salesman appeared. Convenience or advantage are motives for purchase that have to be made evident, awakened and stimulated to action. Gain is a powerful, eloquent voice in all commercial transactions. But to get new business, the salesman or agent must use these forces to attain his ends. Electricity, or the thing to be sold, must show its power to call for the application of these ideas, one, two or all.

Bargains and Small Payments. — Cutting the price of a utensil always attracts attention. Giving people a chance to make small payments always leads to sales. Offering articles of everyday use in a favorable manner is the spirit of modern business.

The principles enunciated are thus illustrated. In the customer, the spirit of gain is quickened by cut-prices. Weekly or monthly payments mean convenience. Articles of everyday use are necessities. Necessity leads to their purchase where they are exhibited or advertised, if the offer is a fair one. Consequently, as current is the product to be sold, all articles consuming it must be emphasized, pushed forward, installed and made easy to purchase, in getting what constitutes new business.

Promoting Wiring, Signs, and Devices. — These belong under the category of gain. The customer gets them for nothing and, of course, is bound to use current to run them. Anything given, offered, used, or consumed as stated, plays upon that part of a customer's instincts which expresses to him the idea of gain. A customer could be induced to wire his place and be promised free service for a few months. Or the company could undertake the wiring free and let him pay for the service he receives. Cupidity, in a sense, is aroused in these cases, unless it be one in which the process is merely one of experiment to ascertain a fact, and then apply it in a business manner. The conclusions in any case, of the way to get new business may be subdivided into departments, methods representing a system of getting business, but the underlying theory as outlined is a broad and enlightening principle of the whole. Perhaps, in a sense, the psychological reasons given for sales, are a better basis to work on, when crystallized in practise than others of a more arbitrary character. Theory, however, in business, while the basis of new action, must yield to experience.

Attitude of the Consumer. — The consumer may *need* the current or utensil; he may find *convenience* in the current or utensil; or he may *gain* by the current or utensil. What is his attitude? This is the point in getting new business. Indifference can be removed by the offering of a gain. But it is natural for intelligent Americans to crave for better things. It is this desire to uplift themselves that aids the salesman. But the chief thing is to adapt the one to the other, the customer to the current or device, on terms that represent satisfaction. In cases where wiring is absent, why would it not pay to put it in, and depend upon the income they ultimately yield in current consumed to pay expenses. Others would pay for theirs in monthly sums forming part of the bill. Promotion wiring should promote. Gain is the instinct aroused by free wiring. Why should not necessity and convenience appeal through it to others? This is the business of the salesman to find out.

CHAPTER VIII

THE SIMPLIFIED RATE PROBLEM OF ELECTRIC LIGHTING

Nature of the Problem.—As billions of dollars are now invested in what is becoming the greatest new industry in the world, it is natural that some interest should be attached to what is at present one of its greatest problems, the settlement of its rate charges. The new industry referred to is that of supplying electricity for light, heat and power. It is quite easy to understand that the day is not far off when every home in the United States will use this form of energy exclusively. This is the natural result of the trend of the times. Everything is being reorganized through the application of electricity. Socially, municipally, industrially, commercially and financially, we are being controlled by the new systems arising through the widespread use of this energy. The telephone places our lips at every one's ear. It has become an indispensable adjunct of every-day life. Socially, our homes would receive a staggering blow by its elimination. The popular apartment house, with its electric elevator and electric lights, is, in architectural construction, more a crystallization due to these inventions than to any other influence.

When the electric elevator fails, the people in the favored apartments on the upper floors are in misery. High living in this sense, is only possible by the devices that it depends on. The same with the use of the electric light and its unexcelled convenience. It has become a positive force in all phases of civilized existence. The Wall Street system depends upon the Atlantic cable, the telegraph and the telephone exclusively. Business men in large cities would be lost without the aid of the telephone and electric light. Manufacturers could not hire labor cheaply, nor have it there on time, did not the trolley carry their workers back and forth from distant homes for a trifle. Out West the heating and cooking in thousands of homes is done only by electricity. To those used to it, its absence would be a hardship. The idea is spreading, and taking permanent root, even in the smallest towns, that electricity is the poor man's friend. Consequently, it is evident that a variety of users must be considered, in all planes of social, commercial and industrial life. To each of these classes electricity has a different value. It is because of this variety of values that the "Rate Research Committee" was appointed by the representatives of the electric light, heat and power industries of the Unites States, in the name of the National Electric Light Association, to try to solve this problem. As they state "The Rate Research Committee has considered that facts dealing with investments and rate of return, are beyond the scope of its work, and has therefore devoted the time at its disposal to the consideration of the theory of rates, and differentiates between the various classes of service, and the proper rates applicable to each."

The matter is really of great moment to the general public, because it must pay the greater part of the bill for all electricity used per annum. The increase in this consumption is very marked. It is highly probable that electric heating will soon come into its own and then the home will be truly electrified. As there are 5,000,000 people in Greater New York, constituting an average of 1,000,000 families, it is easy to see how a dollar's worth of electricity a week for light and heat, would mean an income of $500,000, or $25,000,000 a year. One of the difficulties to-day in this respect, that of popularizing the use of electricity among the poor, is the fact, that their homes are not wired. In the city of Milan, Italy, the laboring classes enjoy all the comforts of electricity, and the company handles profitably accounts that are often as small as 35 cents a month. In the city of Trier even the humblest peasants use electricity in their cottages. The claim is made in this country by many of the electric light companies that they sever a large part of their customers at a loss. This is due to the fact that the interest on the investment made to supply the customer, plus the cost of reading the meter and keeping the accounts is often more than the actual return for the electricity consumed. In Europe, the change from an unprofitable to a profitable basis has been brought about in a large measure by reducing the fixed costs of serving them. This has been done by simplifying the methods of charging, billing and other office operations, so as to make possible the wholesale handling of small customers. The importance of the small and very small consumer in building up the income of the electric light company is recognized to such a degree in Europe that many large amounts are invested by these companies in financing small customers toward payment of the cost of wiring their houses.

The problem of making charges, seems to be that of properly arriving at a system through which all classes of business, industrial, commercial and domestic, will be equitably charged for according to value. The experts chosen to consider these matters grasped the vital idea as far as electric light interests were concerned. They realized that the essence of the difficulty would be that of determining "values." In other words, they arrived at a conclusion which is given: "The problem, therefore, is to determine the value in each case; *i. e.*, what each class can afford to pay, rather than get along without the service. It is not so much a question of what one individual can pay, but of what the class as a whole will pay so as to preserve the balance between the business of that class and the whole, or to readjust the balance so as to use the investment more efficiently."

The Foundation on which Rates should be Based. — To find a common denominator for the conditions which govern rates, it was necessary to pass below the surface of things and reach fundamental principles. To serve the public, to increase that service from time to time and reduce its cost, is a matter that has occupied the attention of experts for many years. The state legislatures imposed restrictions upon charges for electric power in many parts of the Commonwealth. The general public did not freely utilize opportunities as were expected, due to personal bias in the beginning, and as the result of conservatism, and competition by other concerns supplying gas. As a consequence, electric light companies had on their hands a large annual plant expense to meet. The popularization of electricity as a household force has been of comparatively recent date. It is entering the homes of the humble and ceasing to be a luxury. Its use is about to be extensive and, therefore, rate questions must be settled by systems or fiat as speedily as possible. Consequently, the "Rate Committee" have enunciated two principles as a means of formulating rate schedules which they regard as fundamental.

"First. That the rates of the company should, as a whole, produce an income sufficient to give a fair return on the investment and attract capital freely to the enterprise. The gross earnings from the sale of the product must, therefore, be sufficient to cover all the necessary expenses of operation, including taxes, bad debts, etc., a reserve for renewals and contingencies, interest at current rates, and a reasonable profit in addition.

"Second. The Committee believes that when the rates as a whole are giving a fair return on the investment as above provided for, then the rates to separate individuals and classes which go to make up the rates as a whole should be so adjusted as to make the total cost as low as possible, and the service rendered as great as possible, by means of the most effective utilization of the plant."

The Minimum Rate Charge. — One of the questions being argued most vigorously is that of a minimum charge. Many public commissions of different states have considered this question, and their final opinions are of interest alike to the large as well as the small consumer of electricity. The St. Louis Public Service Commission concluded in its report, that those paying the maximum rate be required to pay a minimum of only fifty cents a month, while those paying other rates be called upon to pay a minimum of one dollar a month. The New Jersey Board of Public Utilities also decided that the exaction of a minimum charge of fifty cents per horsepower per month, is not excessive nor unreasonable. In California a decision was rendered as follows: " . . . the flat rate offers no opportunity to distribute the burden of cost upon a fair basis of quantity of service furnished the consumer, because within the limit of the flat rate, the smallest consumer pays as much as the largest.

This principle must not be carried to the extent of preventing the establishment of a fair minimum charge, for this latter is based on the necessity of compelling each customer to bear some part of the burden in furnishing the utility." On this basis it seems that the jurist believed the advantage of having the current on tap, even if it was not used, was worth something, and that it cost the company an amount that ought to be reimbursed pro rata. The Arizona Corporation Commission, handed in a report both unique and interesting on the subject of a minimum rate, as follows: "That the meter rental be abolished. That until further order of the Commission, no maintenance charge for electricity shall be made to exceed $1.50 a month, and in no case shall said charge be made except in case the electricity consumed in any month, charged for at the regular rates, shall be less than the sum of $1.50, and in such case no charge will be made for the electricity consumed." This seemed unusually fair to the public, and although a bill passed the legislature providing that no water, gas or electricity supplying concern could charge for anything but that which passed through their respective meters, when the matter is again taken up, the law will be amended to permit of a minimum charge. In the state of Kansas the rate question has been aired. The council there, in the case of a gas concern, "deemed it proper and reasonable to collect 50 cents a month from each patron, whether he used gas amounting to that sum during the month or not, on the theory that this minimum sum would pay for reading meters and other services. . . ." Human reason seems to turn inevitably to an opinion based upon a minimum monthly payment.

General Conclusions Reached. — In summing up a proposition of this kind two facts clearly appear, and although it seems but reiteration to present them again, they are as follows: First, that the consensus of opinion in many states, the conclusions of many judges, and the findings of many public utility commissions, is to the effect, that a minimum or "least" charge for current is advisable. Second, that the charging for current should be such as to embrace the features of labor and fuel, clerical and outside hire, as are inextricably associated with the operation of a central station. Consequently, it appears, that the minimum rate has come to stay, as an established custom at least. That the minimum rate is a rational and just one, and as such should be tolerated by all patrons. Finally, the charging for current either according to a flat or a differential rate, is entirely a matter of obeying the law first, and following business instincts second, to provide a profit to the station satisfactory to its manager, board, and stockholders. As the uniformity, or steady increase in dividends, is the means by which management is gauged in the hard commercial world, it is evident that in order to secure these conditions, the minimum and other rates charged, must be based upon the idea or "value" to the consumer.

"Value" of the Service Rendered. — Investigations have shown that various rates are necessary in charging for electric energy whether it be used for light, heat, or power. The idea decided upon, was that of determining the "value" of the service to the consumer, whether representing an individual or a class. Consequently, the phrase "value of service rendered" is really the key to the analysis upon which rates are to be built. But to arrive at "value" or *the* value, to a consumer of a given class, would mean a thorough comprehension of the reasons why such rates are determined. A definition of importance, in this respect, was given by the "Rate Committee" covering this point. "The Committee has . . . come to the conclusion that these results can best be obtained by adjusting the various rates to the *value of the service* rendered, giving proper consideration also to the relative costs of service, and defining value of the service rendered, *as the amount which the user would have to pay for the same or equivalent service under absolutely fair but not destructive competition;* in other words, the amount at which the user could serve himself or provide an equivalent or substitute means of service under free but not destructive competition." The idea of charging on this basis is a very fair and equitable one, because the theory involved is to the effect, that there *is* competition. When the charges made by an electric company, are derived from so ethical a standard, the only point to decide would be that of determining the kind of competition existing or imagined to exist. In this respect, the charging is developed on a semi-psychological, instead of a time-worn, and rather monopolistic commercial basis. To pin the matter down and settle it once for all, so as to have it understood that the capital active in the plant is not crushing competition, the "Rate Committee" further state as follows: "It should be noted, that when the total revenue from the rates equals the value of service as thus defined, it will not give more than a fair return on the investment, as indicated, since if competition were absolutely free, another seller might be willing to provide equivalent service and undertake the whole business for the lesser price." This terse, explicit, and perfectly definite statement, is now the new foundation of rate charges.

The Philosophy of Rates. — It is exceedingly interesting to note how logically and justly the new system of charging has been worked out. It is in fact, a philosophy of rates that will stand rigid inquiry and severe criticism. "As competition," as the old adage goes, "is the spirit of business," it is splendid to realize that the consideration of its existence, has not been lost sight of, in the review of the different phases of this subject, by the experts. One of the most characteristic and ennobling features of American manhood, is the idea of a "square deal." The confidence reposed in a man or his business is derived from the expectation that this ideal lives in his heart. To have it reiterated in the findings of a committee, whose conclusions will influence the acts of those controlling over two billions of dollars' worth of interests, is a testimonial to the high honor prevailing in the business methods of the generation of to-day. Keeping in sight the thought of what competition would do, even when it is not present, in dealing with customers and fixing their rates is a Utopian but practical plan. It is evident that the wise heads of the committee realized that fair competition means vitality and longevity to an enterprise; while destructive competition means an end provided by itself. In this sense rates possess within themselves their own virtue to live or to die. The reasoning employed to present this fact is quoted: "Destructive competition, of course, may temporarily force prices down, but in the long run will raise them. There is, however, an intermediate point where fair competition may reduce prices by establishing new and lower values." The question is: "To what level would free but not destructive competition reduce the prices?" The philosophy of rates, therefore, is one based upon the idea of competition on the one hand, and that of value, on the other. The settlement down to figures is merely the result of a logical or instinctive conclusion resting upon a proper appreciation of these ideas. The real problem, of course, is to determine "values." In a general way, these propositions are capable of a broader application than merely the settlement of the charges for electric energy in its various forms. They demonstrate the fact that a business proposition is capable of scientific consideration, and as such consideration is only a reduction down to the primitive test of truth, it is evident that the relations between producer, seller and consumer can always be so considered.

Differences in Rates. — As the result of the different kinds of electricity sold, commercially speaking, different rates would arise, as well as differences due to the "value" to the consumer. Electricity is sold for lighting, heat and power, and the rates for these forms of service have different values. There are also rates given to classes, rates that exceed the value to the buyer, and rates equal to or less than the value to the buyer. It seems evident, however, that when values are once established with respect to one or a group of buyers constituting a class, the only question arising in the future, would be that of a possible reduction due to circumstances that would partly vitiate the original conclusions of "value." These changes could only take place according to the class; it would not affect all classes. But in all such cases, strict adherence is made to the idea of competition and value, and the science of making profitable reductions under conditions which call for them, receives as much attention as that devoted to the original arrangement of rates. To the public, uninformed of the enormous amount of time and thought devoted to the consideration of this important problem, it seems but a simple matter to charge a rate and be done with it, but the new and strict ethics and laws of business forbid this. Rates cannot be charged haphazard, and when arrived at, the reasons for them must be open to anyone's intelligence.

CHAPTER IX

FINANCIAL CONSIDERATIONS GOVERNING RATES

Central Station Securities Safer than National Bank. — Many strange facts come to light on analysis, or by a safe system of comparison with other reliable standards. For instance, in a broad consideration of the factors governing rates, it is evident that few legislators or members of a commission are aware of the technical truths involved, which they are supposed to be perfectly familiar with in order to render an unbiased judgment. It is hard for such representatives of law or regulation to realize the scientific accuracy and careful selection of men and money exhibited by the builders of our great lighting industries. Yet a chart of the annual amounts of securities in receivers' hands in the United States discloses the fact that investments in gas and electric companies are safer, more free from collapse, than the stocks of our much vaunted national banks. As compared with steam railroad securities they are five times as free from receiverships, and about five and a half times better in this respect than the investments in the larger industrials, according to W. H. Gardiner. Rationalism, judgment, economy and efficiency, having thus been stamped upon the moves of our financiers, whose astuteness crystallized in the form of safe securities is a getter guarantee of financial longevity than that of better known investments, it is evident that it is disconcerting to have safe and well-known paths changed to please the ambitions of those unacquainted with the new ones thrust upon the "busy bees" of industry. Yet investigators clearly show that central station securities left alone have been the safest for the public to buy. And the reasons for this safety are not too varied to gather; they are but a reflection of the same clear-headedness that sought perfection in system and mechanism and then insisted on it in finance as well. No one has heard of great electric light or power companies crashing to the ground. Few, if any, trolley companies have passed through this experience except as the directly traceable result of political chicanery too obvious for even the public to fail to see. Telegraph and telephone companies hold their own and improve, increase, pay heavy dividends and cause no concern to their multitudinous owners. But terrific financial cataclysms occur in the steam railroad, banking and industrial world. Perhaps the effects of the new currency bill will be such as to prevent disasters of this kind in the future to which a certain percentage of such cases are traceable. But the facts are as stated, and the superiority of central station securities means, if it means anything, that the judgment and honor of the builders was evidenced by the strength of the structure erected.

The Reduction of Prices or Rates. — Competition is the maker of prices, or such conditions as limit its free play. It is evident that however tempting rates may be, whether made so by law, competition, or co-operation, the purchasing power of the buyer determines the volume of sales. There are definite conditions, internal, vital and sweeping, that affect the purchasing power of the mass as a whole. There are conditions that may be considered that make prices or rates what they are to-day. Essentially, the healthiest of recognized forms of "price influences" is competition. By this is meant, from a broad point of view, the effect of capital upon capital, enterprise upon enterpise. If competition reduces rates without affecting either quality or quantity, the public receives a decided benefit. But should such competition bring about the evil of reduced purchasing power on the part of the workers, the damage done is so extensive that reduced rates or prices will not act as a spur to increased sales. Hence, it seems evident that rates and purchasing power for all commodities are so related, that it would be illogical to radically reduce one if it were known that by such procedure the other would be similarly affected. Consequently, it seems plain, that a limit can be expressed to one of these items, below which it must not go in considering the general prices of all things and the purchasing power of the great mass of the public. In fact, a sane form of rate making is one which provides a profit in service or cash for the customer, as well as the manufacturer. Trolley car service, trains, telephones, telegraphs, electric lights and our mail system do this. No man could do these things for himself as cheaply. He could not transport, communicate, signal, light or deliver his own messages with anything like the cheapness and facility these utilities afford. And this is mainly because they are public utilities, having public functions to perform, which represent a phase of co-operativeness between financial or governmental and public interests. Rate reductions or increases in these fields must be a matter of consent by the citizens where interests are affected. The point, however, is to discover what rates are right, fair and profitable to the investors whose capital has been used to provide an income for them. Unless a public service commission is thoroughly familiar with fundamental truths, it is not competent to change rates as the work is one calling for the highest order of intelligence, acumen and judgment. One curious feature that will manifest itself in the course of time will arise when the investors or stockholders of industrial holdings will be very numerous. For instance, when a $100,000,000 company has hundreds of thousands of small owners. Then the paradox of the public sitting in judgment on itself to reduce its own rates will be witnessed. It seems likely, from the published records of the courts and commissions at Washington and otherwise that the maximum of concentrated capital has been reached. A slow but visible change is taking place, through which all great industrial investments will be represented by a remarkable number of stockholders. On this basis, price and rate adjustments will not be made downwards unless there is a thorough conviction that such changes are imperative.

The Theory of Stock Values. — It is accepted by the average reader as a truism that watered stock imposes a heavy obligation on the purchaser, by its effect upon the earnings of the company. The theory is, that the burden of paying dividends is too heavy to permit of needed improvements being made. Such an obligation, its antagonists claim, is a detriment to normal, healthy processes. As Mr. Gardiner states: "The point is to issue securities in such terms as to get the money competitively in the open money markets of the world as inexpensively as possible. There is the whole problem. And naturally a holding company goes all over the world if its companies need money — into all of the money markets of the world, and finances this class of security in this market, and that class in that market and the other class in the other market, time and time and again rotating them, depending entirely on the money conditions of the world at the particular time at which they are carrying on the transaction." To get money quickly it is evident that companies needing it get it at the best terms they can arrange. Some sell stock far below par, others at par and still others above par. The pressure of circumstances governs this to a large extent.

Yet a heavy watering of stock means a palpable weakness and has its antithesis in the sale of stock at a premium. The whole process should be conducted so that the money is obtained as cheaply as possible. If too cheap or too dear, there is a difficulty present possibly calling for a different operation. A financial expert will probably discover it.

Intrinsic and Intangible Stock Values. — The three great groups of securities on the market at all times are those of steam roads, industrials and public utilities. Where someone's ability is translated into earning capacity intrinsic values are not in evidence. Where the iron, steel, real estate and product is in sight, the intrinsic value is there. A list of market securities will show the difference in character, earnings and risk on the rough sea of business life.

Class of Securities	Market Price in Dollars	Net Earnings in Per Cents.	Risk of Receivership Per Cents.
Steam Railroads	120	4.25	1.84
Industrials	94	7.79	2.07
Public Utilities	90	8.45	0.37

The above table of relationships prepared by Mr. Gardiner was shown in a lecture delivered by him before the West Side Young Men's Christian Association of New York on the subject of Public Utility Economics. This table was presented for the purpose of showing how risks run in connection with certain securities. For instance, per $100 worth of stock issued the risk of receivership is $1.84 per annum with steam roads in comparison with about 37 cents per $100 worth of stock representing public utilities. On this basis, with steam railroad stock costing an average of $120 a share, earning only 4.25 per cent. with a 1.84 per cent. risk of receivership; public utility stock at $90 a share, earning 8.45 per cent. with a receivership risk of 0.37 of 1 per cent. is greatly to be preferred. But the preferredness exhibited by these statistics is due to careful management, which, to a degree is now being modified by legislative demands. Have legislative demands affected steam roads in this manner by deciding their rates for them? The industrials, with larger earnings and the greatest risk of receivership of all can be interpreted as representing more of the intangible form of value than the others. The investments are different, and much less in proportion to their earning power. The inherent point of difference between public utilities and the other securities. The public utilities, however, in spite of their "ever on top" character, are known to be steady.

The "Ever On Top" Service. — A switch may be turned at any moment of night or day and current must flow. Whatever the load thrown on the lines and station it must be met at once. In this feature a distinction must be immediately drawn between service during given hours, service when conditions permit and service at any time. These three forms exist in every large city. Service during certain periods is the store or shop system. Most commodities are thus disposed of in ordinary businesses. As an example of the type illustrating "service when conditions permit" may be found the railroad with goods on a siding awaiting distribution or transportation. The railroad does not undertake to keep them in motion from the moment of their reception until delivery. Here, the public service feature is absent, though it is enforced in other corporations such as street railway and electric light companies. A central station is ever on top. Night and day, at all hours, its energy must be ready for use. This means a readiness to serve, that requires some compensation. It is believed by some jurists that the monthly minimum rate does that. Consequently, it does not seem right to put central stations through the mill as others go. The fact, known to financiers, that it costs more to get money for public utilities than less substantial forms of investment is held to account for the necessity imposed on them to pay more on their securities in the way of dividends. The more profitable and safer investments are disregarded in favor of steam roads because of what Mr. Gardiner aptly calls their "marketability."

Rates Reduced by Mandate. — No other business but that in which the company receives a license or franchise from the public, is forced to make its rates suit it. A Federal Rate Commission of scientifically trained experts, deaf to public clamor arising through demagogy, would be a sort of supreme court before which to place situations of this kind. Local commissions, however well meaning, are apt to fail to realize the full meaning of conditions. To establish a paying business a "going value" must be obtained. To secure capital obligations are entered into which are a drag on future profits. Altogether is it evident that rate setting by mandate does not meet the situation as it should. No objection could be raised against absolutely competent commissions, but it is inevitable that those constituting such a body are not necessarily adapted to decisions of this kind. Externally, the problem appears to be one calling for a very simple solution. Internally, the conditions require deep consideration. A heavier burden is forced upon the stock of public utilities in paying a large dividend than steam roads. Until this injustice is remedied, fixing rates is no expression of the public sense of equity.

The Effect of "Tight" Money on Rates. — A few words on this subject from the pen of an authority on finance will dispel any illusions that may exist as to the effect, the dire effect, of "tight" money on rates. This does not mean that money is "tight" in a natural sense, but that it is hard to get for the purpose required. However, a broad view of what stringency means will not be amiss in this brief monograph on the subject of rates. Victor Morametz in his series of papers published by the *North American Review*, entitled "The Banking and Currency Problem in the United States" states the case as follows: "As the whole amount of currency used as a circulating medium by the people never exceeds *three-fifths* of the entire currency in the country, it is obvious that the currency is ample for the uses of the people as a circulating medium. When it is said that money is tight, or that a strigency exists in the money market, this does not mean that there is insufficient currency in the country to meet the needs of the people for a circulating medium. It means really, that people cannot obtain loans and discounts from the banks, because the banks are unable to grant further credits, their reserves of lawful money being insufficient. It means either that the banks and trust companies have expanded their deposit liabilities in relation to their reserves to the limit of safety, or to the legal limit, and that they cannot lend their credit any further by the creation of deposit liabilities, or else that they feel compelled to call in loans so as to increase their reserves or to reduce their deposit liabilities. It does not mean that the people cannot have all the currency they want for circulation, unless, as recently, the banks actually suspend cash payments. Even when the banks suspend cash payments, and there appears to be a currency famine, as in the recent panic, the real cause of the trouble and the source of danger, is not the inability of depositors to obtain currency from the banks. This inability to obtain currency was an inconvenience, but not very serious, because, generally, debts could be paid by check. The seriousness of the panic arose from the fact that the banks, having expanded their deposit liabilities in relation to reserves beyond the limit of safety, were compelled to call in loans that could not be paid immediately without enormous sacrifices, and were compelled to refuse to make loans and to grant credit for legitimate and necessary business purposes." The public has been exposed to these influences, financial stresses and strains, regularly, at approximately set periods. Whatever have been the causes one of them has now been removed. It cannot be said that the money system of America is not elastic. At present this is an established fact. "Tight" money may result from over-production, and the resulting closing of factories for a while, until the product is consumed. But these conditions should not leave a scar on the country's prosperity again. Rates, therefore, can be settled according to existing circumstances. "Tight" money no longer means a a prospective panic, as such a disaster is now impossible. Why then, should not all surplus be invested in stocks and bonds of public utility concerns without unusual fears or expectations? The broad publication of the fact that such investments are unusually safe would make it easy to secure money for them, with the reduced cost of getting money, the reduced necessity of paying so much on the shares and the consequent reduction of rates pertaining to such utilities.

Earning Power and Safety of Investment. — The earning power and safety of investment are related as shown by tabulated results exhibited by Mr. Gardiner in his lecture previously referred to. These tables clearly showed that the group of companies that had the least receivership risk had the largest net earnings per $100 worth of securities. In concluding his lecture he stated: "In view of all these statistics, it is difficult to understand why, as I have previously shown, public utility securities sell at 90, while railroad securities sell at 120, excepting by the supposition that the investing public is intimately acquainted with railroad securities, but knows comparatively little of public utility securities." This is the whole problem. Convince the public the other way and its money for such securities will be easy to secure, it will cost less to get it, and less will have to be paid on such securities. Such a financial change will lift a burden from such companies in the way of fairer dividends averaging up with those of better known companies. As a net result, the expense being less, the rate can drop in a healthy manner without being forced to do so by any form of legislative action.

CHAPTER X

THE BASIS OF RATES FOR CURRENT

How Charges Vary. — The physician, lawyer, expert accountant and chemist, represent widely divergent professions to an extent. The purpose of their work is to live, to get a wage. They may work because they love their profession. They may use it as a means of obtaining wealth. Whatever the underlying reasons to them, they do not hesitate to charge for their services. These charges are not and cannot be uniform. They may make them so because of competition, but the fact that the value of the services rendered differs in many respects, makes it rather difficult to do other than acknowledge one thing: that charging must be based upon value as much if not more so than a common or uniform basis logically difficult to establish.

Sociological Aspects of the Rate Problem. — The customs prevailing are the result of experience, tradition or fiat. In studying the rate problem of central stations or any other phase of it in other fields, the logic leading to the establishment of certain rates, to allay public clamor, is often faulty. From a scientific point of view, the public is but a group of families. Living in close communion, this group presents characteristics it would not so vividly present as separate and smaller communities. The framing of public opinion may be due to excitement more than reason, emotionalism more than consideration. To obtain the approval so sweet to politicians and parties, price adjustments are sometimes made to please the public. Establishing a rate for handkerchiefs or potatoes in a sense is similar. One is made of flax or cotton, a vegetable product subject to climatic changes and market manipulation. The other, without further change, is placed directly on the market. Did the law force these two items to be sold to a certain class at a certain price, would not the other class have to pay more to compensate for inevitable losses?

The Rate Committee of the National Electric Light Association touch upon the subject in these words: "Adjustments of prices to particular classes are sometimes made by controlling authorities for so-called sociological reasons. It should, however, be noted that attempts to solve sociological problems by means of low public utility rates are usually inefficient. A high rate for purposes of limiting business, like the saloon tax or tax on phosphorus matches, may be worth while, but giving unnecessarily low rates to any particular class only results in unnecessarily high rates to some other class. It is clear, however, that any class that pays an unusually high rate could pay a direct tax just as easily while there would be an intermediate class who would have been able to have the advantage of the service at a fair price, but are prevented from using it at all if asked to pay a higher rate, and this is to the public disadvantage."

A Supplying Company Withholding Service.— Competition is called the spirit of business. According to the theory of competition, whether in electric light and power service or otherwise, free production and free consumption are the governing factors. By this is meant the practically unlimited manufacture of a staple article, consumed, so to speak, to an unlimited degree. Under such circumstances, it is presumed, as borne out by fact, that the cost bears but little relationship to the quantity made. The idea underlying this point is that this form of competition affects all classes equally. From this it can be deduced that there are two kinds of competition: the kind affecting all classes equally, and the kind affecting all classes unequally. When a thing is of equal value to all people, the charges for it are equal. When a thing is not of equal value to all people, the charges for it are unequal. A barrel of potatoes in Ireland will not fetch the price that a barrel of potatoes would in New York, or at a fur station at Hudson Bay. Consequently whereas there are two kinds of competition, there are also two kinds of charges. One set of charges may be below cost, or at least be insufficient to pay a profit. Another set of charges or rates may be necessary to pay for these reduced charges. In other words, one set of buyers paying more, make it possible for another set of buyers paying less to get the goods. The Rate Committee treats of this analysis of competition and charges in the following manner: "In the case of so-called staple articles, which anyone can make or use, and where the cost has but little reference to the quantity made, competition establishes a market price or rate, uniform sometimes over the whole world. Here competition affects all classes equally. When, however, competition affects classes unequally or when cost varies, under different conditions, rates are not uniform, but vary with conditions according to the values in each case.

Starting with any rates, whether a single uniform rate or a complicated schedule, if such rates are not already adjusted to values, then they can be modified to the advantage of the community by so adjusting them. When they are not adjusted to the value, it means that there is a potential buyer who would pay a real profit but who fails to get the service because he asked too high a rate; or else there is an actual buyer who is paying so little that he is an actual loss and is being supported by the other buyers, and is really receiving a subsidy from the other buyers in order that he may use the service.

It should be noted that when a supplying company withholds service from any potential buyer who is willing to pay more than the added expense of supplying him, then the refusal of service hurts all the other buyers, since, if he were supplied at a rate that showed *any* profit at all, the additional business obtained would, in the long run, help the other buyers.

However, the rate asked from him, if it is going to be *lower* than that charged the other buyers, should be *just as high as he can afford to pay*, but when it is just as high as he can afford to pay, then the fact that it is lower than to the other buyers is of no disadvantage to them, while the profit that he brings in is ultimately for their advantage. It is assumed, of course, that the rates are the same to all buyers supplied under the same or substantially the same conditions.

From this point of view it is evident that a supplying company withholding service is very apt to fall into error to the ultimate disadvantage of the central station, unless the rate demanded be too low to allow a fair profit.

Determining Values. — The modern way of doing business is to find out what business ought to be done, and do it. Determining rates is a very important part of central station business, but to determine them, the science of procedure must be evident. To determine rates, however, logic demands that we ask "Upon what do rates depend?" Rates, according to the brief résumé of the subject thus far, evidently depend upon values. Values, therefore, are entities to be considered specifically or generally. But analysis has shown that rates rest upon two fundamental principles. Service to the public will be successful only if it be supplied on a business and commercial basis. This means that the technique of central station processes, and the technique of service to the public in a commercial sense, must combine and harmonize in an adjustment of the two, called satisfactory rates. Consequently, as the object in general should be that of giving the greatest service for the least money, as well as making provision against conditions known and feared by those engaged in industries, principles that may be applied conducive to this end should receive the approbation of business men, central station managers and electrical experts. These principles are given as follows:

"*First:* That the rates of the company should, as a whole, produce an income sufficient to give a fair return on the investment and attract capital freely to the enterprise. The gross earnings from the sale of the product must, therefore, be sufficient to cover all the necessary expenses of operation, including taxes, bad debts, etc., a reserve for renewals and contingencies, interest at current rates, and a reasonable profit in addition.

"*Second:* The Committee (Rate Committee) believe that when the rates as a whole are giving a fair return on the investment as above provided for, then the rates to separate individuals and classes which go to make up the rates as a whole, should be so adjusted as to make the total cost as low as possible, and the service rendered as great as possible, by means of the most effective utilization of the plant." A further paragraph by the committee touches upon the meaning of competition and the value of the service rendered. "The committee has further come to the conclusion that the results can best be obtained by adjusting the various rates to the *value of the service* rendered, giving proper consideration also to the relative costs of service, and defining value of the service rendered as the amount which the user would have to pay for the same or equivalent service under absolutely fair but not destructive competition; in other words, the amount at which the user could serve himself or provide an equivalent or substitute means of service under free but not destructive competition." Thus, for the determining of values, it it evident that the idea of competition must enter. This competition, as stated, must not be destructive, but free and fair. It involves the idea of one being able to serve themselves. This means a basis for charges which cannot be questioned from the standpoint of fairness and good business.

The Two Kinds of Competition. — Value of service rendered has been defined, as the amount which the user would have to pay for the same or equivalent service under absolutely fair but not destructive competition. Competition that is fair is open. Competition that is not fair is destructive. If the form of competition reduces prices only temporarily, the rates after it is over will be higher. The only competition that is useful is that which adjusts prices to a healthy basis. But the effect of competition is to make new rates, which different classes of business utilize to produce new returns. The old status is never the same. Inevitable changes take place, and it is hard to return to old conditions of previous service. Destructive competition, of course, may temporarily force prices down, but in the long run will raise them. There is, however, an intermediate point where fair competition may reduce prices by establishing new and lower values. The question is "To what level would free but not destructive competition reduce the prices?"

"This case of reduction of rates caused by competition, due to excessive profits or to a reduction in the seller's costs, is one thing. The other case is a reduction of some rates only because of some new method of doing *parts* of the business, as when electricity took the lighting business from gas, but did not compete with gas for cooking."

Competition, therefore, may be broadly defined as two ways of doing business: one, that is constructive, healthy and permanent, by fair competition. The other, which is destructive, unhealthy and temporary by unfair competition. Consequently it must occur to every well-balanced business man that there is really but one kind of competition, the kind that is really the spirit of business. This affects the different classes of business upon which fair competition acts. The different classes of business must be discerned and carefully noted if the effect of competition is to be noted upon them. In all these transactions the point to be kept in mind is that values must be determined, what each class can afford to pay rather than get along without the service. It is not so much a question of what one individual company, but of what the class as a whole will pay so as to preserve the balance between the business of that class and the whole, or to readjust the balance so as to use the investment more efficiently.

Profitable and Unprofitable Reductions.—As the fundamental idea in business is profit through service, it must be evident that what is called a reduction is simply the making of a new price. Whether this price prove profitable or not depends upon two things: the acumen of the price-maker and the attitude of the public. The making of the price must result from a course of reason and experience inviting that figure. This must be based upon the popularity of the new rate and the possibility of new business that will prove to be profitable as well. The Rate Committee, speaking of "Unprofitable Reductions," state as follows: "If the reduction in rates results in new business, that involves additional expense greater than the additional income, thereby reducing the net income, such a rate is less than the cost or value to the seller, is unprofitable, and does not satisfy the requirements of the cost of service tests. Such rates would not be made under free competition, except when reasons of company policy are the determining factor rather than the value to the seller." From this point of view, the income of a plant must be drawn from sources that are directly or indirectly profitable or injury is being done. This injury may be threefold: to the buyer, to the seller, and to the company. The peculiar, not to say remarkable effects of certain rates can only be grasped beforehand by astute minds. Rate-makers really comprise a select, scientific and exceedingly capable class of men. In large industries, department stores and public utilities, the rate making or setting of prices is a delicate and exceedingly responsible business. Reducing prices or rates can only be done by experts steeped in experience, or the results will be unprofitable and possibly disastrous. In discussing the "Case of Profitable Reduction" the committee state as follows: "If, however, the reduction of the rate to the prospective buyer is (1) down just to the value to him, so that business results, is (2) not below the cost or value to the seller, so that it brings in more added income than the added expense, and (3) does not involve any reduction of income from other buyers, then the result is profitable to the seller."

A profitable reduction in rates is one through which more business results because of its popularity to that class or others which it affects, and the growth of more consumers through the greater ease of canvassing, who do not increase the expense, but the profit. The committee continue the analysis of cases of profitable reduction by saying that "These reductions have no immediate effect on the new buyer. If the rates to an individual or class that formerly did not buy are made just the same as the amount they formerly paid for equivalent service, such customers are no better and no worse off, since they continue to pay the same amount as before, but to a different seller. Such a rate gives the prospective buyer no advantage that he did not already have.

"These reductions have no immediate effect on the old buyer. The old buyers continue to pay the same rates they formerly paid, and all the competitors of the old buyers continue to pay what they formerly paid, though to a new seller.

"These propositions, however, depend on the price to the *prospective* buyer being just the value to him and *no lower*. If the reduction be too great, it might be an unfair advantage to him and a disadvantage to his competitors who continue to pay the old price.

"Such reductions are always possible until finally all classes that can be supplied are supplied, and this means a balance between the amounts of business done in the different classes so as to use the investment most efficiently. The result of these reductions is at first an increase of profit to the seller."

Disposition of the Profit to the Seller. — "When the profits to the seller are increased so as to be excessive and to exceed a fair return, whether by such a reduction as described or by any reduction in the seller's total costs, then the original seller should reduce the rates or a new seller is likely to come in and do business at lower rates. It is the province of commissions that regulate the prices of monopolies to regulate prices along these lines so that the public may obtain substantially the same prices they would obtain under fair competition and provide that the public and the seller jointly may share in the savings that come from the avoidance of any unnecessary duplication of plant. However, unless some of the profits are given to the seller, there will be no incentive to him to plan for a reduction of any sort, and this profit for the seller above an ordinary return is only his fair return for the extra skill in management, initiative risk or energy that make the reduction possible."

General Conclusion Regarding Rates. — Rates, as thus discussed, seem to be indicative of a state of mind on the part of the sellers, as well as a certain business condition internally satisfactory and profitable. It does not seem desirable for concerns to amass swollen fortunes as a surplus. It does not seem desirable for a selling concern to intend to act upon the public as a unit to be forced. The idea of compulsion creates antagonism and competition. There can be an agreeable, confidence-breeding relationship between the seller and the classes supplied. This constitutes idealism in business, the seller, with the full knowledge of the consumer, taking only a profit which he himself would take. And this state of affairs is not only most desirable, but the inevitable way which will result from the proper attitude of one to the other. Each is necessary to the other's existence, and the act of one to tyrannize in rates over the other is opposed by all the agreed rules of social relationship. Business in this respect is not injustice or oppression, but fair dealing. Managers must realize that excessive profits may be more of an indication of unsatisfactory business methods and only temporary success than otherwise. Several well known corporations have unwisely thrown their reputations to the winds by ambitions of this character. The final effect of it is an awakened public opinion, the selection of commissions, and a revised set of rates. Publicity of this sort is undesirable to-day. Corporations and companies must bear good names as friends of the public. The advertising of products per annum costs untold millions, and it seems unreasonable to spend money lavishly this way and yet use methods which produce unfavorable criticism, and thus annul the very purpose for which the money is spent. Therefore, the best rates are those which produce a reasonable profit to the seller and a maximum service to the consumer.

CHAPTER XI

RATES TO CHARGE FOR ELECTRIC POWER

Small and Large Lots of Power. — The production of power is regarded as a technical success. The transmission and distribution of power is also accepted as an economical process superior to any other the mind of man has thus far devised. But the commercial handling of this power is still an unsolved problem. And the problem appears in all its complexity when small and large lots of electric power are to be sold. This may be power for either lighting or non-lighting, to be delivered near the center of supply or far away. It may mean the delivery of a quantity of small lots, or it may be but one or at least a few deliveries of large lots. It may be a case of distributed lighting in a straggling town, or an instance of near-by delivery to many customers in large or small quantities. In each case the cost varies, the manufacturing or producing source has to reach out further or more often to supply the power, and thus encumbers itself with an expense practically fixed and to be paid by the consumer accordingly. The "Rate Research Committee" have patiently investigated this point and their remarks are appended: "Hence in making a rate, physical conditions or time or place can be used alone, since such differences in value apply both to the buyer and the seller, but if use is to be made a test of value, this can be done only when some other tests apply also to the seller; as for instance, the output or time; and vice versa, if output affects value to seller, it can be applied only when one of the other tests also applies to the buyer." The meaning of this latter phrase "test of value" and other expressions, will be best understood in connection with the conclusions of this committee, one of which was, that producers of electric power have in the past aimed to serve the public first, and thus made it necessary for them to tinker with their rates so as to increase this service as much as possible. This modification of rates from time to time was forced upon the electric light and power companies by the competition of private or isolated plants in part, as it was otherwise brought about, by the need of keeping the investment productive, that is to say, the large and increasing sum needed for a complete station and distributing equipment. From these points of view the investigations led on to two definite conclusions.

Two Conclusions of the Rate Committee. — The two fundamental principles which the committee felt free to elucidate are as follows:

"First: That the rates of the company should, as a whole, produce an income sufficient to give a fair return on the investment and attract capital freely to the enterprise. The gross earnings from the sale of the product must, therefore, be sufficient to cover all necessary expenses of operation, including taxes, bad debts, etc., a reserve for renewals and contingencies, interest at current rates, and a reasonable profit in addition.

"Second: The committee believes that when the rates as a whole are giving a fair return on the investment as above provided for, then the rates to separate individuals and classes which go to make up the rates as a whole, should be so adjusted as to make the total cost as low as possible, and the service rendered as great as possible, by means of the most effective utilization of the plant." The point of vital interest to be presented, however, is that entitled the *value of the service* rendered. The interpretation of this idea, projected by the committee, suggests a pending solution of the problem, *meaning of "Value of Service Rendered."* Value of service rendered is defined as the amount the user would have to pay for the same or equivalent service under absolutely fair but not destructive competition; in other words, the amount at which the user could serve himself or provide an equivalent or substitute means of service under free but not destructive competition. The idea thus presented is one which governs the entire arrangement of rates if once adopted. The purpose of the investigating committee being to suggest, that the rates charged be proportioned to the value of the service rendered. The rates therefore would apply to a class of grouped users as well as large individual consumers. It is evident, that like the tariff, it will take skilled and astute minds to properly determine these rates. The determination of them will actually control the success of the lighting company, perhaps determine its policy, too. In which case the rates are essentially and fundamentally the life of the business itself. They can not be so made as to provide an inordinate profit but only a reasonable return on the investment, for it is evident, that if competition ensued, as might be imagined as the cause of the rate charged a consumer of current, the effect of it would be to reduce the profit to a certain percentage. This would be acceptable and safe commercially as it is in other businesses. It would not be so, however, if the competition were destructive. The Rate Committee in speaking of "Rates as a Whole" refer to this condition quite emphatically. They say "It should be noted that when the total revenue from the rates equals the value of service as thus defined, it will not give more than a fair return on the investment, as above indicated, since if competition were absolutely free, another seller might be willing to provide equivalent service and undertake the whole business for the lesser price." It may be noted with respect to this last statement that the governing influence in charging certain rates is that of imagining what a theoretical competitor would charge and still make a reasonable profit. This is the basis of the rates, and the system by means of which a logical series of charges are to be made depending upon the extent of the consumption and the character of the consumer in this theoretically competitive sense implied and emphasized in the findings of the "Rate Committee."

Meaning of Fair and Destructive Competition. — Fair competition speaks for itself, it lives. Destructive competition on the other hand destroys itself. Its intention is to destroy its opponent by the slaughter of prices. But the very slaughter indulged in is unsustainable and eventually the prices rise. Fair competition tends to lower prices, but not too low, not to a level where reasonable profits are impossible. There is nothing menacing in fair competition, whereas in a war of prices the object is aggressive and militant. The Rate Committee in this respect ask: "To what level would free but not destructive competition reduce the prices?" It answers with reference to lower rates by saying: "This case of reduction of rates, caused by competition, due to excessive profits or to a reduction in the sellers' costs, is one thing. The other case is a reduction of some rates only because of some new method of doing *parts* of the business, as when electricity took the lighting business from gas, but did not compete with gas for cooking." But these things occurred after values had been established in some way. In other words, a reduction of rates is only possible, whether by fair or destructive competition, after values have been decided upon, charged, and largely accepted. To get at these values is the thing, and any way of arriving at them throws light on the general proposition: the proper rates to charge consumers for electric power.

Profitable and Unprofitable Reduction of Rates. — The effect of prices is discovered in the profits. The cost of doing business must not absorb them. The simple law of exchange and barter governs this. An unprofitable reduction in rates may mean new business, but that will mean an income less than the cost to the seller. The value to the seller must be equaled at least by the income, or money is being lost. An unprofitable reduction in rates brings this about, and it is not dictated by business but rather by company policy. As value to the seller is disregarded in such a reduction, it is evidently not one due to fair or free competition. Consequently, "If the reduction in rates results in new business that involves additional expense greater than the additional income, thereby reducing the net income, such a rate is less than the cost or value to the seller, is unprofitable, and does not satisfy the requirements of the cost of service tests." From this standpoint, unprofitable reductions, affect a principle that must be grasped, that the cost of service must not be assailed in any transaction called reasonable.

A profitable reduction in rates presents three interesting aspects: First, it represents a value to the buyer, productive of business; second, it is not below the cost or value to the seller, so that it brings in more added income than the added expense; and third, it does not involve any reduction of income from other buyers. These three items are worthy of serious contemplation, because the adjustment of rates can only be made commercially, which means profitably, if they are made logically, which means scientifically. The general effect of such reductions is to gain business from sources otherwise closed. The philosophy of the system is that of placing electricity at everyone's door at a price that makes it of value to them. But to make it of value to them is not possible by any generalized method, because the cases or classes of cases to please are many. There are new buyers to consider, to whom the rate, though reduced, is just the same as it was when they purchased electricity or gas elsewhere, there are old buyers and prospective buyers to consider.

New, Old, and Prospective Buyers. — The "Rate Committee" investigated the types of buyers from these three standpoints, in their extensive analysis of the rate question. They found different states of mind resulting from a reduction of rates depending upon the *time* of a customer's acceptance of service. As this, though commercial, is psychological and inevitable, the full words of the committee are given: "These reductions have no immediate effect on the *new* buyer. If the rates to an individual or class that formerly did not buy are made just the same as the amount they formerly paid for equivalent service, such customers are no better and no worse off, since they continue to pay the same amount as before, but to a different seller. Such a rate gives the prospective buyer no advantage that he did not already have.

"These reductions have no immediate effect on the *old* buyer. The old buyers continue to pay the same rates they formerly paid, and all the competitors of the old buyers continue to pay what they formerly paid, though to a new seller.

"These propositions, however, depend on the price to the prospective buyer being just the value to him and *no lower*. If the reduction be too great, it might be an unfair advantage to him and a disadvantage to his competitors who continue to pay the old price."

Thus, the idea of fair play, resides at the bottom of the system being developed. It is evident that this honorable basis is an encouragement and a satisfaction, because it is so clean and practical as well as strictly commercial. The commercial feature is that of getting the most out of the investment, the capital laid out on the internal and external equipment. In addition to this is the capital invisible but invested in obtaining a "going value" for the plant. This is not found in machinery or lines, but in development, getting a start, and pushing things along. Therefore, it seems, that profitable reductions as outlined are always possible if made on an ethical, scientific and commercial foundation to strengthen the position of both company and consumer. In other words, "Such reductions are always possible until finally all classes that can be supplied are supplied, and this means a balance between the amounts of business done in the different classes so as to use the investment most efficiently. The result of these reductions is at first an increase of profit to the seller."

The Determination of Values. — The whole question of rates seems to revolve about one point: arriving at the value of the electricity, to the particular consumer. The problem, therefore, is to determine the value in each case; i. e., *what each class can afford to pay, rather than get along without the service.* It is not so much a question of what one individual can pay, but of what the class as a whole will pay so as to preserve the balance between the business of that class and the whole, or to readjust the balance so as to use the investment more efficiently. Consequently it is evident that values are to be determined by classes and investment. The classes represent groups of "rate similar" consumers. The investment is what calls for a reasonable return after rates are settled. The two forces external to that of "value" to the consumer as presented, are those of class and investment, as essential arbitrators. In purchasing goods or shopping for prices, under free competition, it is possible to get a better rate as a rule. The one unaccustomed to this practise will fail to realize the best values. The government, however, forbids any difference in rates for this reason, and demands that whatever differences may be available, within the limits expressed, be open to all, regardless of the fact that individuals have more or less skill in obtaining results in this manner. The idea of this is the protection of a certain class against coercion. In this sense, in fixing a value or rate, the government acts paternally, as a father would act to protect a helpless child against marauders. This attitude on the government's part, may mean excessive expense to the supply agent in many instances. The "value" of the current to the consumer may be much greater than the cost to him. Thus, the idea is frustrated: that of supplying a customer, within limits, at a "value" in harmony with its need to him. In this respect, the "Rate Committee" speaks as follows: "Adjustment of prices to particular classes are sometimes made for so-called sociological reasons. It should, however, be noted that attempts to solve sociological problems by means of low publicity rates are usually inefficient. A high rate for purposes of limiting business, like the saloon tax or tax on phosphorus matches, may be worth while, but giving unnecessarily low rates to any particular class only results in unnecessarily high rates to some other class. It is clear, however, that any class that pays an unusually high rate could pay a direct tax just as easily while there would be an intermediate class who would have been able to have the advantage of the service at a fair price, but are prevented from using it at all if asked to pay a higher rate, and this is to the public disadvantage."

Values are broadly determined by *time* and *place* in the case of many commodities. The correct determination of values in a strictly practical sense, therefore, would be to apply some broad rule like this, to effect a widely acceptable conclusion. Time plays its part because of the variations in a temperate climate, of the seasons. Place plays its part, because commodities have values dependent upon where they are.

Time and Place Values.—As fruits, vegetables, ice and other things, have a "time" value, simply because they can be obtained plentifully and cheaply at certain seasons of the year; so it is evident, that electricity has a "time" value. This is true of it in summer, and at certain times of "off peak" load. Thus the thing itself has not materially altered, any more than fruits in and out of season, but the value is affected intrinsically, being cheaper when plentiful and not so much in demand, and dearer, conversely. As regards "places values," coal is an excellent example. In the coal seam it has one value, at the pit another, and when in bulk after transportation, still another, etc. In the case of electricity, the power of which is extracted from coal or from water power, the value is different in the station or at the falls. It is different, after being delivered a number of thousand feet, or some miles away. The cost of transmission involves the external investment of a power supply plant. The same entity is being considered all the time, but its different conditions and times of use give it automatically different values. The *time* value is governed by the *storage* of the commodity. The *place* value is governed by the *transportation* of the commodity. These are general means of estimating values.

Use, User, and Output Values. — Doctors, lawyers, ministers and others determine the value of their services by the particular case on hand. This is, aside from the friction of competition, the general way in which commercial business is conducted. But when a variety of values are to be considered, the method fails. In the case of a large factory and a private residence, the difference is emphatic. The rates have to vary. In considering the "use" value, in electric light and power supplying, the light rate as distinguished from the power rate, is a test of value according to use. The "use" idea is one governed by the ease of substitution as well as the cost. The electric motor is substituted for the steam engine. The electric power is substituted for the steam power. The use idea is employed by the government in its postal service. One can send a letter, send a postal or transmit a circular to impart information. Each has a different use, a different purpose or application. Hence, the government recognizing this, charges different rates. The rates depending upon the use, and those depending upon the user, have differences that may be noted.

The "user values" are also limited by the possibilities of substitution. Such users as churches, some societies, charity organizations are distinctive. They are given certain rates for obvious reasons. If others had these rates they might resell and kill the higher rates. Telephone companies charge different rates to private homes and places of business. This is a test of value according to "user." While apparently one of "use" and not "user," the social phone might be, and often is, much busier.

The "output" value is of interest as well. Cost does not go down as output increases in all cases. Small dinners cost less per plate than large banquets. A village, or small-town telephone exchange, does business cheaper per head than a metropolis. A "physical" value test is one in which products of the same thing have different values. This is true of kilowatt hours, ampere hours, kilowatts of demand, etc. The five tests of value given, that of time, place, use, user and output are essential. The physical test is made in instances as well. These are the basis of all rate charges to-day.

CHAPTER XII

WHAT THE RATES MUST PAY FOR

Sir William Thomson's (Lord Kelvin's) Rule. — The essence of Thomson's Rule, with respect to transmission plants, is that the cost of the power wasted in the lines, should not exceed the interest on the investment in copper. This gave a limit to the investment, one that was obtained by the strict laws of mathematical investigation, in fact, by the calculus. The expression "the interest on the investment" was interpreted to mean, that part of the investment in which the power was wasted. Whatever it meant, or however obsolete some may think that law has become to-day, it at least points out the fact, an unimportant one too, that there is a limit to investment, governed by the losses. For it is not difficult to see that the distributing section of a central station of large dimensions has taken on many of the characteristics of a transmission plant. The smaller ones covering a large territory, would take on these features, as the volume of business forced their growth. And many now possess both features: that of the transmission plant, and central station or distributing center. Consequently, the science of finance has a problem to deal with — which might be entitled in non-technical speech, the limitation of investment. Whatever called it is one basis on which rates are largely made.

The Limitation of Investment. — Banks supply capital to business men at a properly gauged rate of interest. There is really no favor done, for the bank lives, pays its expenses and creates a surplus, by loaning money. If business men did not borrow money in this way, the banks lose their greatest earnings. The business man's note is his promise to pay. The business man's character and standing is his guarantee. His energy, enterprise, development and success insure his credit. With established credit and sufficient creative ability, an individual meets with no formidable setbacks. A group of individuals with an astute leader under such conditions can rear a giant monolith of business enterprise.

The second phase of business development is where the capital is obtained from the public. In this case, the capital the public supplies is loaned with a certain earning power attached to it. A speculative interest is also attached to the money, as by the purchase of stocks or bonds, the varying demand makes their value respond as an increase or diminution. Whatever enterprise is thus floated and supported, the power to earn on the money invested, marks it as a failure or success. Intrinsically earning power is not money, but it is capitalized nevertheless. This is a characteristic of many industrial corporations. Consequently the capital invested in them has a peculiar significance and difference from those corporations whose capitalization is expressed by an equivalence of value in land, mines, buildings, machinery and actual money. Although, therefore, earning power is not money, yet its power to make money is considered as identical with capital for all practical purposes. Investment spells earning power, and the expression is used as a financial synonym for it. The limitation of investment is that point at which capital acts as a redundancy. It is a critical degree of investment which is made to meet periods of low earning as well as high earning power. It is a point in financial expansion at which money does not lose earning power when interest rates rise, yet sufficient to have an active and satisfactory earning power when interest rates fall. This, at least, is one interpretation of the phrase, "The Limitation of Investment."

Relationship Between Cost of Station and Cost of External Equipment. — A leading banker has said: "In the long run commerce suffers more from the periods of over-abundance (of money) than from those of scarcity. The origin of each recurring period of tight money can be traced to preceding periods of easy money. Whenever money becomes so over-abundant that bankers in order to keep it earning something, have to force it out at abnormally low rates of interest, the foundations are laid for a period of stringency in the not far distant future, for then speculation is encouraged, prices are inflated, and all sorts of securities are floated until the money market is glutted with them." This, of course, has its bearing upon the limitation of investment, in the sense, that an unscientific form of investment, is no other than one that would be condemned by financiers. It is one that would mean a disproportionate amount of stock floated to the capital invested, earning capacity, and future earning capacity of the plant. Such a condition would lead to the necessity of paying dividends on stock that had been sold, and whose only intrinsic value lay in the dividends paid on it.

The earnings, therefore, would have to meet this strain. This would mean a rate for power, current, or whatever the exchange value or commodity would be, that could not be reduced. Under such circumstances, the organization would be systematically strangled and exhausted by the steady drain on its vitality of this abnormal financial cancer — the dividends paid on watered stock. The promoters and founders are those who fatten on such proceeds. The relationship between the cost of the station proper, and that of the external equipment is of financial interest; for by this consideration, arise the means of comparing the internal and the external costs of operation. Three cases may arise under such a form of investigation:

First. That of a central station whose outside equipment and machinery equipment are of equal cost. In this case the investment is capable of increase, as for instance, in a new enterprise.

Second. That of a central station whose outside equipment costs less than that of the station proper.

Third. That of a central station whose outside equipment costs more than that of the station proper. It can be well understood, that the greater the external development of a plant, the more successful it is *per se*. This means extensive business, increasing customers, but also increasing expense. An over capitalized station, is either one of which an immense volume of stock was issued of a dividend paying character, but doing a large business; or one of a limited outside business, still to grow, against which the future was discounted in the issuance of a disproportionately large amount of stock. The bearing of all this upon the rates to be charged is obvious. For if the financial expense is excessive in proportion to the business done, the only way to avoid liquidation is to pay such expenses until such time as the volume of business and its additional profits warrant a change. Under such conditions, the rates cannot be conveniently altered without the risk of difficulties, unless such alteration assures a larger volume of business at once.

In a plant with a large external equipment, with an excessive stock flotation to handle, the problem is a ticklish one. Any central station can charge a minimum rate productive of profit provided its expenses will permit it. But in central stations whose development is such that the outside investment only equals the inside or is even less, and having stock dividends to pay or possibly interest on bonds as well, the earning power will not permit a lowered rate unless there is a certainty of new business in sufficient volume to warrant it.

The question, therefore, hinges upon the dividends on stock, interest on bonds, insurance for fire or casualty, the rate of depreciation, cost of repairs, cost of fuel, cost of publicity, cost of wasted power and the allowance that should be made for innovations, such as a new system of machinery and operation. This question must also include the salary list, the expense of which may be a source of increased income in total or may represent a percentage of dead wood. When the external equipment is enormous enough to make the consideration of the central station expense proper, only a percentage of diminishing size of the total expense, attention would be concentrated upon this, first. Then a minimum rate can be more readily adopted than with variable elements of expense, as in the case of a station doing a business established on no certain basis and too subject to the influence of changing seasons.

Cost of Wasted Power. — In the mining of coal, the waste amounts to millions of tons. In one respect the cost of this is added to the purchase price. The customer pays for the waste, the freight, the middleman's profit and the handling. But the railroad and the large central station can close contracts for coal at an exceedingly low price. The difference between the price the retailer pays and those constituting themselves the wholesalers is very great. In this respect, because of the original low cost of the fuel the cost of the power wasted is not very high. But this is only considering it as fuel and not as having been put, so to speak, through an elaborate machine called the central station, from which it issues, familiarly speaking, as electricity. The value of the wasted power and the cost of this self-same power are different items. A merchant considers his stock as possessing a certain market value, even if it is given to him. So may the electricity be considered that is wasted in C^2R losses in the transmitting, distributing and generating sections of the plant. Lord Kelvin, therefore, had in mind the limitation of the investment when he referred it to the cost of wasted power. For what rule of finance warrants a heavy investment when there is a heavy drainage? Consequently, with a system that is practical, it is presupposed that the investment will be reasonable as well.

Each customer is, therefore, adding to the losses in the plant as well as adding to its profits. The losses he adds to are: the interest charges, insurance, depreciation, repairs, wasted power, etc. The advantages added to are: increased earnings, reduced publicity and increased power consumed with respect to the power lost. Of the power lost this much may be said: that if it is reduced, the effect is the same as an addition to the plant. If the effect of a ten thousand dollar investment is to produce a hundred kilowatts of service, it is evident that in a million dollar investment the reasonable diminution of the wasted power acts proportionately in the same manner. If the waste of this character is increased a hundred kilowatts, it is as if a pro-rata investment had been added.

In a plant producing 100,000 amperes and losing from 5 to 10 per cent. of the pressure, the loss is not only 5 to 10 per cent. of the energy and the coal, but really 5 to 10 per cent. of the total investment. Therefore, in a plant costing a million dollars outside to complete the equipment and a part of this to complete the central station proper, the percentage of wasted power — if from 5 to 10 per cent. — relates to the million or more dollars comprising the whole investment. Therefore wasted power represents dead equipment, lost money and a partial paralysis of the plant. In street railway service this is excessive, but is well paid for, because a passenger investing five cents only uses up a part of this amount in actual power consumed for locomotion. Were it otherwise, electric railways would absolutely fail, through an inability to earn enough to pay in addition to the vehicular power required, the necessary money for car labor and office expenses. These items are, of course, all collected out of the nickel.

Improved Equipment. — Some one must pay for the up-to-date equipment when an advance in modern invention calls for it. The change from high speed to low speed engines, the introduction of the multipolar in place of the bipole generator, the installation of the steam-turbine, the transformations in boilers and forced draught as well as stoking systems, as well as the actual enlargement of the station itself, all took a heavy outlay of capital. And this does not include the long years of experimentation with the questionable success and therefore profitless years of earlier days. No one can say what momentous change will transform the station of to-day into an entirely different institution — as to its time of coming or extent. The inventive electrician is not a stationary item, but very active and revolutionary. Therefore a decade from now may mean as much as all have witnessed in wireless, in the tungsten lamp, development in aerial navigation, or other forms of remarkable accomplishment. Therefore the cash to pay for new equipment is an item of importance deserving the right to a sinking fund of its own.

Justice in Charging a Rate or Rates. — Finally, the principle that must govern any suggestion regarding rates must be simple justice at its least. This justice must apply to the central station as well as to the customer. It is not always possible to lead the customer behind the scenes to show him the complex system on which charges are based, but it is at least possible to prove that the charges are rational and just, not empirical and flavored of czarism. The recognition of the expense of operation is one none can deny, because the station is there, the coal is burnt, the employees must be paid and the office must be run. All that a business man contends with on a small scale, unless the business he runs is enormous, is what the central station manager contends with on a large scale. The merchant sells his goods according to a well-known system. The manufacturer produces his goods according to a well-known system in most cases. What the merchant charges is more or less controlled by competition. What the central station charges as a maximum is generally regulated by the Legislature of the State.

What Is a Reasonable Rate. — The courts are deciding "what is a reasonable rate" as well as those who are financially and technically interested in central stations. The *New York Supreme Court* states as follows: "The law does not contemplate that the defendant shall do business at a loss. It is expected that it will, and it is entitled to, make a reasonable profit on its venture, and the sole question in such a case as this is, whether the charge made is unreasonable, considering all the defendant is required to do, to meet each customer's demand. . . . The customer does not bind himself to use any particular amount of light, so that the return to the company based on actual consumption, would rest entirely upon his volition, and it would therefore depend upon him whether the service he has required the corporation to be in constant and immediate readiness to render, is profitable or unprofitable to the latter. But this constant condition of readiness is a necessary and unavoidable obligation, which must be sustained, in order to meet instantaneously the demand for light, which the consumer is entitled to have at any moment that he wishes it. It thus forms a part of the service to be rendered, and is an item properly to be considered when the reasonableness of the charges exacted by the company is called in question. . . . They are free to exact a reasonable return for the service required, which includes, as I have said, not only the actual supply of electric light, but the readiness to supply it.

One consumer with the same number of lamps will use more than another. In both cases the return to the company may be remunerative, or the use of one may be so inconsiderable as to involve a loss. To meet this contingency the monthly minimum charge of $1.50 is made. But it must be borne in mind that this payment is not in addition to the charge for actual consumption. Where light is consumed which entitled the company to payment, on meter measurement, of a sum per month equal to or in excess of the so-called minimum charge, the customer pays only for the light he has actually had; so that this fixed charge becomes practically operative only where his consumption falls below the extent of use which it measures."

The reasonable rate, therefore, seems to be, legally and technically, at least a minimum rate, which acts protectively for the company's benefit. Another reasonable rate seems to be a rate adjusted in accordance with the volume of consumption. Merchants operating a large manufacturing plant are not in the habit of giving prices to the small purchaser, on their goods, as they will to the large purchaser. This is human nature and a custom as old as established trade. And if the manufacturer was obliged to keep open day and night, to serve the small purchaser whenever he called, there would be quite a change in the present prevailing prices of any such commodity; and any objection to such a charge, in the face of what the manufacturer would construe as a hardship, would be considered by him unreasonable and unjust. The fact that the public is accustomed to such day and night service should not diminish the value of its convenience, nor the responsibility and expense of providing it, in its eyes, at least. As the product of the central station — the factory — is kilowatt hours, this stock or output should be sold in agreement with existing laws and such reasonable and agreeable customs as have prevailed in the merchant-guilds from early times until to-day. Let favor be shown the purchaser, who by his purchase reduces, per unit, the cost of handling or conveying it.

CHAPTER XIII

THE MINIMUM RATE CHARGE

The Public Service Commission. — A jury sitting in judgment on the facts, for the purpose of suggesting remedies, or adjudicating a given case of public importance, though called a Public Service Commission, is presumably a body of representative citizens trying to settle a municipal problem in a businesslike way. There is no reason why the conclusions of a group of able citizens, should be less important than the individual opinions of well-known and successful business men. In a jury or commission there is no chance for flights of oratory of a biased or sense-befuddling character. There is little reason to expect an hiatus in the consideration of a problem of common importance. Consequently, the subjection of the items, to the sober judgment of representative citizens, is a natural, profitable, and rational process. Service commissions are becoming more and more important in the management of the business affairs of towns. They have become such, that some communities are entirely governed by them. Were the members of the commission able to devote all their time to the public cause, no better system could be devised than that of governing or regulating the affairs of large communities exclusively in this manner. The Public Service Commission is therefore a return to a liberal and just method of obtaining the truth with respect to a civic proposal or a condition that needs amelioration at once.

The Commercial Handling of Merchandise. — After all, the sale of merchandise must be carried on according to the laws and customs of business. It makes little difference whether that merchandise be the common articles of household use, or the more valuable and less plentiful things that constitute the luxuries of life. The consumer pays for the things he needs, and it is this steady consumption which determines the cost of production, the selling price and the general conditions of sale. Though electricity is regarded as a mysterious force mysteriously produced, by the public at large; when the time comes to pay for it, it loses a great deal of its unusualness, and quickly falls into the category of ordinary products. The consumer demands the privilege of paying for it in a way comprehensible to him. And the fact that technicalities seemingly block the way to a definite conclusion, do not in the least detract from the need of presenting the matter in a manner businesslike and final. As in the commercial handling of merchandise, the sale is made on the basis of a definite quantity for a definite price per item; so, in the commercial handling of electricity, it has become necessary to finally adopt a basis of this kind, acceptable alike to the commercial and technical experts in the business. The charging for electricity is and must be based upon the fundamental laws of production, demand and cost; and along these lines it is possible to arrive at some conclusion regarding the proper rates to consider harmonious with public policy. Many public service commissions of different States have considered this question, and their final opinions are of interest alike to the large as well as the small consumer of electricity.

The St. Louis Public Service Commission, Mo. — In the Report of the St. Louis Public Service Commission to the Municipal Assembly on Rates for Electric Light and Power 1911, is given a thorough analysis of cost of service, which is the basis of the schedule of rates recommended therein, and the report upholds a "cost to serve" charge as distinct from the consumption charge, as equitable and just. The conclusions stated are: Customer's charge is an exceedingly important factor in establishing residence rates, and items admitted to the charge need to be closely scrutinized. As the amount of the maximum rate takes into account the full amount of the customer's charge, the present custom of requiring a minimum bill of one dollar per month should not be allowed to continue where the customer pays the maximum rate, but in order to protect the consumer and the company against the possible addition of large numbers of customers who might require connection simply for occasional use of the current, the Commission believes that a minimum bill of fifty cents a month should be required of the consumers paying the maximum rate. In all other cases a minimum bill of one dollar is considered just.

New Jersey Board of Public Utilities. — It is equally interesting to note the conclusions reached in New Jersey by the Commission. The points entertained and passed upon by this board were systematized and arranged succinctly and categorically as follows: First, that the exaction of a minimum charge is a reasonable rule or regulation for an electric lighting company to make. Second, that the making of this charge by the month is just and reasonable, and is really more equitable than if the charge were made by the year. Third, that a charge of $1.00 per month "per plant for installation" is just and reasonable, but that a charge of $1.00 per meter is excessive where more than one meter is installed. A minimum charge of 50 cents per month per meter, however, is not excessive or unreasonable, for each additional meter installed on the same premises, for the same customer, supplied through the same service. Fourth, that where a customer requests that service be discontinued for a period of at least a month or more, the minimum charge should be waived during such period. Fifth, that where a customer requires the service for a limited period only, a reasonable charge may be made for the work of connecting and disconnecting the service at the beginning and end of the short period. The minimum charge is part of the rate schedule, and should be incorporated with it whenever it is compiled for examination by the public.

Further remarks were handed in by the Commission relating to the Power Service. These opinions will be given, as they clearly demonstrate the desire for fairness in the distribution of the cost of service on the shoulders of the big as well as the small.

Power Service, According to the New Jersey Board of Public Utilities. — From this comparison, it does not appear that a minimum charge of 50 cents per horse-power per month is excessive or unreasonable. It is undoubtedly true that the exaction of a minimum charge will result in an apparent hardship to a small number of customers who use their equipment but a very short time, in some cases not more than four or five hours per month. The fact must not be lost sight of, however, that the supply of electric power is strictly a commercial proposition, and to relieve one customer from the payment of any considerable portion of the cost would merely result in transferring the burden to other customers, and such a transfer does not appear to be justified. The Board, therefore, determines that in connection with the furnishing of electricity for power purposes, the exaction by a company furnishing such service of a minimum charge at the rate of 50 cents per horse-power per month is not excessive or unreasonable. The Board further determines that the smallest minimum charge now made in connection with electric power service, which is $1.00 per month, is likewise not excessive or unreasonable. In the following is the reasoning with respect to gas rates by the Board.

Concerning Charges for Gas Consumption by the N. J. B. P. U. — It is pretty generally agreed to-day, that a properly constructed schedule of gas rates, will combine two different kinds of charges, a minimum charge, and a charge graduated by consumption. A gas company has two different kinds of expense. The first consists of the charges arising from having built and having to maintain, a plant and delivery system. This charge is largely independent of the quantity of gas consumed. It would exist, if no gas at all were consumed for a time. The other kind of charges, for fuel, labor, etc., will vary largely with the total product manufactured and delivered. A fair minimum guarantees a return on plant built, maintained, and held in readiness to serve. A fair charge for the amount of gas consumed, affords a return for the second class of expenses. A proper schedule will combine both minimum charge, and a metered consumption charge, and is fairer, and more advantageous, in the long run, to both consumer and producer, than the ordinary provision now operative in Ocean City (the concern in question considered by the N. J. B. P. U. being the Ocean City Gas Light Co.).

The Two Necessary Charges in Electric Lighting. — It is evident from this brief review of the circumstances, that two definite classes of expenses must be considered. First, the expense due to the installation, and its readiness to deliver current, as a fixed institution, before any current is consumed. Second, the necessary expense due to the production of electricity in the station and the costs associated with that expense, which include labor, fuel and other items.

This is a rational basis for the consideration of the charge, and clearly indicates the need of what has so far been popularly termed "a minimum charge." In the first case, the minimum charge is one made on the basis of the plant, maintenance, and readiness to serve. Naturally, the two sets of expenses differ: that of the plant as a concrete whole, and that of its operation as a current producer. To those who are connected with the central station, and have agreed to use its power, a relationship of a co-operative character exists. There is no reason why the expense should fall upon one pair of shoulders, that is to say, the company's. The co-operation is of a character which means convenience to the company's patrons all around. They have the instant use of a large and exceedingly complex organization at any time they call upon it. They may use little or much electricity, and be charged only as it is consumed. But the fact that they do not use any, yet remain connected to the foci of supply, does not relieve them of the responsibility such a connection implies. It is not reasonable to expect the lighting company to support this burden alone. It is only just that it be equally divided among all customers, and thus place a little of this responsibility upon each patron, instead of it being borne solely by the financial department of the station.

The Charge Due to Current Consumption. — As regards the charge due to current consumption, the practise discovered in many, if not all States, is to the effect, that the charge for current, if no greater than the minimum rate, shall only be collected at that figure. In other words, if the charge for current is greater than the minimum rate, the minimum rate is included in the charge, as though all that is being paid for is the current consumed. But the wisdom of this method of charging is discovered in the fact, that if 1,000 patrons use no electricity for a month each year, the income on the basis of a minimum rate does not cease. Otherwise, with the plant fully equipped it would be at the mercy of the patrons at all times. Now, the fact of importance in connection with this matter, is that the plant is not operating after midnight and until late in the next day with any considerable load. For this reason, it has an operating expense, with little income, the greater part of the day. Did the plant operate equally at all hours to its full or even to half its full earning capacity, the method of charging would be altered. But the internal conditions are such, that the charging for current must be considered with respect to them. In a decision on flat rates given in California in connection with the water company's charges, the following appears: "Furthermore, the flat rate offers no opportunity to distribute the burden of cost upon a fair basis of quantity of service furnished the consumer, because within the limit of the flat rate, the smallest consumer pays as much as the largest. This principle must not be carried to the extent of preventing the establishment of a fair minimum charge, for this latter is based on the necessity of compelling each consumer to bear some part of the burden in furnishing the utility." The charge for current consumption is therefore sufficiently distinct from this other charge for the furnishing of the utility, that its final consideration from the standpoints of practise, is one of interest and instruction. Flat rates are those which continue uniformly through whatever consumption is continued by the customer. Differential rates are those which vary according to the extent of the consumption. But, as was noted in the California Commission's report, flat rates possess the defect of giving no opportunity to distribute the burden of cost upon a fair basis of quantity of service furnished the consumer, because, as was therein noted, within the limit of the flat rate, the smallest consumer pays as much as the largest. On the other hand, the law requires a charge no more than a given figure per kilowatt. Consequently, the arranging of rates must be made to comply with the law sufficiently, to raise no question of special accommodations in one case as compared with the other. The rates to heavy consumers of current ought to be such that they do as well with the current of the central station, as they would do, were they operating a station of their own, due consideration being given to the difference in investment and responsibility involved.

The Case in Arizona about Rates. — The different States have a variety of views concerning the most advisable charges for current. In Arizona particularly the Commission met and concluded that the following items correctly covered the points considered by them. As quoted, the record reads as follows: The Arizona Corporation Commission has handed down an interim rate order of date, September 14, 1912, containing the following clauses: That the meter rental heretofore made, charged and collected by the defendant company, is hereby abolished. That until further order of the Commission, no readiness to serve or maintenance charge for electricity shall be made by the defendant company to exceed $1.50 per month, and in no case shall said charge be made except in case the electricity consumed in any month, charged for at the regular rates, shall be less than the sum of $1.50, and in such case no charge will be made for the electricity consumed.

As a corollary to this pronouncement another statement must be quoted in the case of the Arizona Commission. The following statement of date, November 7, 1912, by Mr. W. P. Geary, chairman of the Arizona Corporation Commission, indicates the views of the Commission on this point: The last session of the Legislature provided by statute, that gas, electricity and water measured through a meter, would be charged for, according to the exact amount used, and that no other charge should be made. This, however, does not meet with the approval of the Commission, and we expect that when the Legislature again convenes (probably this month) this law will be amended so as to permit a minimum charge being made.

The Supreme Court of Kansas. — In Kansas the rate question entered the courts and had to meet with consideration there. The conclusion here as in other cases, was to the effect that the illuminant used (gas in this case) was to be consumed subject to the minimum rate idea. To quote: "The Council evidently deemed it proper and reasonable to collect 50 cents a month from each patron, whether he used gas amounting to that sum during the month or not, on the theory that this minimum sum would pay for reading meters and other services performed by the city in connection with the service, although the amount of gas used in one month might not entitle the city to this sum. The regulation being one contained in an ordinance, it is presumptively reasonable until the contrary is shown, or unless it is unreasonable or discriminatory on its face . . . and it not appearing *prima facie* unreasonable, but reasonable, it must . . . be upheld."

General Conclusions Reached. — In summing up a proposition of this kind two facts clearly appear, and although it seems to be but reiteration to present them again, they are as follows: First, that the consensus of opinion in many States, the conclusions of many judges, and the findings of many public utility commissions is to the effect that a minimum or least charge for current is advisable. Second, that the charging for current should be such as to embrace the features of labor and fuel, clerical and outside hire as are inextricably associated with the operation of a central station. Consequently it appears, that the minimum rate has come to stay as an established custom at least. Secondly, that the minimum rate is a rational and just one, and as such should be tolerated by all patrons. And finally, the charging for current either according to a flat rate or a differential rate, is entirely a matter of obeying the law first, and following business instincts second, to provide a profit to the station satisfactory to its manager, board, and stockholders. The uniformity or steady increase in dividends is the means by which management is gauged in the hard commercial world. To secure these necessities in central station work, the minimum rate must be established along with a profitable charge for current.

CHAPTER XIV

LIGHTING AND BILLS FOR LIGHTING

The Light People Use. — The light people use is supposed to be the light they need. Wasting it is on a par with wasting food and water. Yet the feeling of many when they pay a bill is that they are sustaining a loss for something which, though needed, is still an intangible thing. What electric light bills actually represent is not recorded on the tablet of their memories. The often vast network of subterranean wires, the busy station with its night and day watches, the coal burnt, the generators and engines in operation — all of these are unrecognized or forgotten while the bill is being paid. It seems to be the opinion of experts, however, that much light paid for is wasted, and, therefore, the reason that the discharge of the obligation is sometimes keenly felt is because some instinct tells the same thing. Waldemar Kaempffert in a letter states, "We are measurably nearer the day when our electric light bill will represent not so much money paid to the power company for losses between the coal pile and the illumination that converts night into day, but rather so much light profitably used. The new metal filament lamps prove that. They will soon completely displace the carbon filament lamps and cut down lighting bills by more than 50 per cent. besides giving more light." The fact seems to be from the presentation of the case that the public are growing accustomed to more for its money than ever before, in consequence of which an uneasiness is discovered when public-service corporations are paid.

Profits. — It has been the experience of men doing big business for quite a term of years, that the development of a system and a plant of a semi-public character, is regarded askance by the general public. This is particularly true when the demand for a lower price is resisted or an extension of any public need is called for. It is at its heart a criticism of the men in charge of the administration of affairs, though the dart is not openly but covertly aimed. The promulgation of the idea, that all aggregations of capital and machinery are basically dishonest, is sufficiently widespread to be the belief of the superficially-minded. But the realization of the fact that most men are honest and the majority holding positions of trust live up to high ideals dispels this fallacy and aspersion. The management of the central stations of this country has been particularly clean. The margin of profit between earnings and cost has not been so enormous as to merit unjust or unkindly criticism. It will be admitted that it took time for experience to demonstrate the cost of a kilowatt in a large city and thus establish a rate; but with the increasing cost of coal, wages and material in general, the cost varied in spite of improvements in the machinery employed.

Electric Light Bills. — What electric light bills represent, therefore, is not an arbitrary relationship between cost and the manager's opinion of profit. It is hardly the view that would be taken in any other line of business. And selling electricity is as much a business as the sale of any other commodity. But rather, it might be said, that electric light companies all over the United States, are in competition, and this relationship has had the same effect in settling the average price of a kilowatt as competition in other cases.

The call for electricity is greater in some parts of the country than others. In those vicinities where the call is greatest the price is regulated to be reasonable to the customer and satisfactory to the central station manager. In other vicinities where the call is light and the enterprise new, the expense is very heavy in proportion to the income. If the charge seems a little high at first it is only because the demand is not great. It is quite evident that if a business grows rapidly and is well patronized the average cost to each is less than where time and money have to be spent to produce results. What applies to any legitimate business applies to central station service as well.

The Illuminating Engineer.— The new era has brought the illuminating engineer into a substantial existence as the first aid to the central station. To find the kind and amount of light a merchant, manufacturer or home-builder needs, is his problem. The illuminating engineer knows how to make any mixture of light demanded. The exact equivalent of daylight, or a light that has plenty of yellow, blue or red rays can be produced as required. The light can be added to or subtracted from. Dr. C. E. Kenneth Mees in an able article shows how rays that are dispensable are strained or filtered out. The method of examining light to find its constituents is also in the scientific, artistic, yet intensely practical work of the illuminating engineer.

The vast increase in industries, and the need of various kinds and intensities of light to further these activities, have been the necessary means of establishing a logical branch of engineering. The theory of optics was regarded as a branch of physics to be studied as an academic requirement. The change from theory to practise, to direct invention, has been so pronounced that no man can say what is least or most useful in science. This is very true of light as well. One of our writers in the field of the illuminating engineers has this to say. "You are right in stating that artificial daylight is probably not the best light. Only the manufacturer of textiles, the artist, the lithographer — in a word, the man whose chief business in life it is to match colors, really demands an exact equivalent of daylight. Most of us would be quite content with a light of pleasing color that is efficient." This fair survey of the situation is sufficient to prove the contention often made that the glare, the pitiless whiteness of daylight is frequently injurious. The relief of gazing at green grass, foliage and flowers is evident. This is why the decorator has a fine profession. He tones a room to suit the eye and thus the intellect as well.

The Tungsten Lamp. — In the electric light field the effect of a radical departure makes itself felt in various ways. The tungsten lamp takes less power than the carbon filament lamp, therefore the central station is apt to have less of a call made upon it than before for its quota of energy. This fact has been noted by H. B. Gear, in an article by him, entitled "Handling Tungsten Lamps." He states as follows: The reduction of energy consumption may be checked by encouraging increased standards of illumination among existing users of electric light and the creation of new business where other forms of illumination have been in use heretofore. The experience of gas companies in increasing the standard of illumination without largely decreasing the consumption of gas when the Welsbach mantle was introduced has demonstrated that it is quite possible to accomplish results along this line which will prevent existing customers from taking the full benefit of the reduced energy in changing carbon to tungsten lamps. The various schemes which are being tried to accomplish this result depend largely upon rates and local conditions, so that no general rules can be formulated beyond the suggestion that the increased amount of light received from a given amount of electricity should be made to produce new business where other illuminants have been in use heretofore.

Cost of Tungstens. — On account of the increased cost of tungsten lamps the problem before the central station was not a simple one. The customer wanting to get more light for the power he was paying for naturally turned to tungsten lamps, which the central station had to supply at a certain figure. If it is permitted the use of them so that only the same amount of light was produced as before then the current bills fell and the company lost money, or at least its receipts were less than before. Then the breakage in connection with tungsten lamps was another item to consider, with the cost of lamp renewals. In his article Mr. Gear states as follows: "The high cost of tungsten lamps and the fragile nature of the filament necessitates some means of charging the customer for lamp renewals which shall be in proportion to the size and number of lamps used. This cannot be readily done by adding to the rate charged per kilowatt-hour for electricity for various reasons. It has been done in a few cases where four-light tungsten clusters were furnished on a special form of contract, which requires a separate meter for the tungsten lighting; but in general this is impossible because of the use of carbon lamps and other current consuming devices on the same meter with tungsten lamps. Where the central station does not furnish the first installation of the carbon lamps free of charge, the tungsten lamp is sold to the customer outright, in some cases at regular rates and in other cases at reduced rates which are approximately equal to the cost of the tungsten lamps.

Charging for Lamps. — The practise of charging the customer the full retail price tends to encourage the installation of lamps of as low voltage as the customer can use and therefore results in greater loss of income than is the case where it is made easy for the customer to get larger sizes of lamps. Where the first installation of carbon lamps and renewals are furnished free tungsten lamps may be furnished at a reduction of from five cents to ten cents below company cost, to give the customer the full benefit of the price of the carbon lamp, which he would otherwise have used. It seems wise not to allow the customer the full benefit of the price of the carbon lamp, as the percentage of breakage of tungsten lamps is higher than with carbon lamps, as well as the unit cost of the lamps themselves.

For instance, if a group of customers use 1,000 tungsten lamps, during a stated period in place of 1,000 carbon lamps, the loss by breakage might be about 5 per cent. or 50 lamps. Assuming that the tungsten lamps were distributed between the 25, 40 and 60 watt sizes, the average cost of broken lamps would be perhaps 60 cents. The value of the 50 lamps would be, therefore, about $30.00. This is equivalent to an extra cost of three cents per lamp on 1,000 lamps and must, therefore, be allowed for in fixing the amount which the customer is to be allowed, in view of the fact that he does not use carbon lamps.

These adjustments are necessary in view of the fact that as progress goes on new conditions arise which must be understood and met. The methods of to-day are the ones which get business, not those of a generation or even a decade ago. The central station manager is forced to be up to date or he will discover his mistake in the dwindling prestige and receipts of the central station he controls.

Good Light. — "Good light enables employees to work better — which is the dollar saved. Enables customers to buy better — which is the dollar earned. And it makes everybody feel better — which has a dollar and cents value that cannot be measured. Good light means more product, better product — with less waste; more sales, better sales — with less complaint and less expense of doing business. Poor light means blunders, accidents, 'rejects,' 'seconds,' payroll loaded down by sick absentees, patrons uncomfortable and going somewhere else where the light is good, though hardly conscious that the light is the cause." These remarks emanated from the brain of a man paid thousands of dollars a year to advertise the merits of lamp chimneys and reflectors; and it is within the discretion of the reader to decide as to whether his purpose is sufficiently accomplished. The writer makes a point of the fact that good lighting is not common, and that scientific illumination is a new subject not quite understood by the public and existing as an art entirely in the minds of a few trained scientific men. On account of this state of affairs it (the company) has put out an easy book entitled "Scientific Illumination," covering the fundamental points of perfect lighting, covering, wiring, lamps, glass, etc. — without prejudice in favor of any lamp, method, system or glass. As the pamphlet is supposed to suggest, it helps you to start right in the light problem.

The proposition as then put is exceedingly interesting to the trained as well as the lay mind. In a naïve manner the advertising writer makes the inquiry, "Why should we do this — publish a book on illumination when our business is making glass?" and the writer answers his own query in an equally interesting and instructive manner by the statement: "Because our business is illumination — glass is a most important part of illumination. The right glass distributes light effectively and without waste. The wrong glass destroys efficiency. The final statement is this: We will give you such information or advice as will strengthen your good light and your profits, and root out your poor light and your losses. This applies to everybody — big and little — homes, hotels, stores, restaurants, railroad stations, factories, public buildings, office buildings, individual offices, libraries, and the Capitol at Washington."

Good Lighting. — Without in any way intending to or indulging in any humorous reference to the last item, namely the Capitol at Washington, which seems to reach the highest altitude as a climax of thought in the mind of the advertising writer, it is our humble but sincere wish that every intelligent man and woman in the United States had a copy of the pamphlet referred to in their possession. And in stating this wish, the reasons given are not as obscure as might seem to be the case at first sight. The general public has a very hazy idea of what is needed in a place that might be brightly lit. It is not sufficiently conversant with the facts to be in a position to demand specifically the right thing. If the lighting in a place is bad, in a general way the public complain about the condition. If the lighting is good, possibly little is said, for about the same reason that one has little to say about the dress of a well-dressed man; there is nothing that attracts attention by either its superfluousness or its deficiency.

The public is the goal and the lighting is the means to reach it. The distribution of millions of pamphlets throughout the country would mean the widespread influence of an idea that would take root here and there and finally grow to bud and flower. Out of every thousand circulars a certain number are retained and read. If every one were read and forgotten the effort would have been a failure. If every one that was read was discussed by an intelligent man to a group of friends, the effect would be of the best possible character. Yet of them all a certain number reach home, and pro-reasonable than to see that they have good food and air, or, in winter, good clothes. After all, it is a question of health, and health is the wealth of the poor man. In other ways it is a question of humanity, and that at least is the question of the hour. Could the estimate be made, there seems little reason to doubt the fact that poor light annually causes a loss of millions of dollars, but the trouble is in getting at the facts in such a way as to prove the case in full.

CHAPTER XV

THE PREPAYMENT OF CURRENT

Conditions Existing in Gas-lit Areas. — A large meter factory is kept busy in Connecticut turning out thousands of prepayment meters for the gas lighting companies there. The fact that there are such devices in general use is known to not a few. It is best known, however, to thousands of families living in houses taken by the month or season. The reason why prepayment meters are used at all by the gas companies, is because they find that the best and cheapest way to handle their business in such communities is in that manner or not at all. One of the largest corporations in the world engaged in the manufacture of electrical apparatus says this: "The extraordinary success attending the introduction of prepayment gas meters, both in America and Europe, has been generally accepted as indicating that a large field of usefulness exists for prepayment electric meters." This is particularly true, to present a special case for illustration, in summer colonies at the beach or in the country. Here, the gas company, in the usual run of cases, lays the service, installs the prepayment meters in all cottages requesting them, and is content to gather the harvest of a few months' returns. The fact that a certain fixed community remains after the season is over naturally explains this generous treatment. But the point about it is, that in the country, where the kerosene lamp superseded the whale-oil lamp, and that the candle of two generations ago, is now being superseded by gas, introduced for the first time in many homes only by the use of the fair and square prepayment meter, called in many sections of New England — the quarter meter. In gas-lit areas, therefore, there are two classes of business: one is that of the substantially fixed and somewhat permanently situated member of the community of the middle class; the other is that of the class who go to where work is to be found. One class is needed and is always sure of occupation. The other class is unskilled, is not always needed, and, therefore, is apt to be often out of work. In the aggregate the latter class consume a large volume of food and necessities. They need gas for cooking and light. Though moving on at certain intervals others take their place, and the quarter meter, to a class thus sociologically defined, is a boon whose value is not lightly measured, yet proves a source of income to the gas companies in securing business not otherwise attainable. For these reasons, prepayment meters have their place and use.

The Central Station View of Prepayment Meters. — The general statement that may be made is that the cost of the collector who collects, may be more than the profit he collects. Many customers vanish from a community and become a dead loss. Others, who use up the substance of the gas or electric company, are not what one would call a good financial risk. They also add to the cemetery of dead accounts. Then there is a class who pay, but who reason as they pay, and their reasoning is as follows: "Why should we accept a flat rate and possibly not use what we have contracted to pay for. Let us have a metered rate, and pay at the month's end for what we use according to what we consume." A large electrical concern manufacturing prepayment watt meters has this to say on the subject: "Most consumers of electrical energy prefer metered service to the payment of flat rates, but there are always a large number who are not prompt in the payment of bills and who cause much trouble for the collecting department. In many cases these customers are not financially responsible, and in the course of a year the loss to the operating company amounts to a considerable sum. With metered service it is impossible to arrange for payment in advance, and the problem of insuring protection to the company furnishing energy was unsolved until the advent of the prepayment integrating watt meter. Not only will this meter insure the lighting company against the non-payment for energy used, but offers advantages to the consumer as well. There is no possibility of error in bills due to carelessness in taking meter readings, and the resulting complaints from consumers are eliminated. Customers are also relieved of the trouble and time necessary to go to the office to pay bills, or the annoyance of a collector, and the expenses of his service to the lighting company are dispensed with."

The Time-Switch Action of a Prepayment Meter. — The prepayment has great usefulness in such fields as sign lighting and window illumination for stores. By inserting the proper number of coins, the sign, display window, arc lamp, or other device may be automatically extinguished at a predetermined hour, thus obviating the necessity of a watchman's services to perform this duty or placing time switches. In this manner a separate account of the display may be used to great advantage with Cooper-Hewitt charging outfits and motor-generator sets. Where a certain amount of energy, equal to that paid for by the inserted coin is all that ought to be used, the prepayment meter is a superior device to employ. It has great advantages in connection with central station work, because it gives limited power for a limited sum and then the operation ends. The merchant displaying goods in his store window, or the electric sign man, can find in its application exactly what he requires in these instances. Costs and efficiencies are now the subjects most considered in commercial circles. "Costs" is well covered by a prepayment meter. But efficiency is a subject of vast interest and many interpretations in business. Electric power for lighting, heating and motor service is now almost an essential in all branches of up-to-date industries. Cost, as previously stated, can be determined and controlled. Efficiency, however, is dependent on ratios of values. One group of these are costs, expenses; the other group in a way are receipts or earnings. Devices regulating both are a boon if properly applied. A prepayment meter can obviously control cost by only giving out electricity as the coins are dropped in. In the same manner it is a guaranteed collector, because it collects before it delivers the goods. For these self-evident reasons mechanisms of this type are a decided advantage for certain classes of central station business that managers cannot afford to ignore in these times.

General Construction of a Prepayment Meter. — The Westinghouse prepayment integrating watt meter is similar in electrical and mechanical details, with the addition of the prepayment feature, to the operating mechanism of the Westinghouse Type B watt meter which has given such universal satisfaction. The addition consists essentially of a circular dial and pointer, a coin slot and a circuit closing mechanism. When a coin is inserted in the slot it strikes a wheel, releasing a spring which closes the circuit through the electro-magnet of a switch connected to the main circuit. The coin dial is plainly marked in ten divisions representing a quarter of a dollar, that being the size of coin for which the meter is designed. One or more quarters up to ten may be inserted at one time, the amount of current paid for being indicated by the position of the pointer. As each quarter is dropped in the needle moves one division. For instance, if there are ten divisions on the scale, and the money in shows the pointer standing between 7 and 8, an additional quarter dropped in would make the large pointer assume a position between 8 and 9. The pointer is so connected with the train of gears, that records the consumption, as indicated on four smaller dials, that as the current is consumed the large pointer travels backward until the amount paid for is entirely used and the pointer reaches zero, when the current is automatically cut off. If the needle points between 7 and 8, for instance, it means that the consumer has nearly seven and one-half quarters to his credit, or about $1.88. An ingenious arrangement is provided whereby any coin smaller than a quarter will pass through the slot without operating the mechanism. The coin receptacle will hold a total of forty quarters. The meter can be adjusted for *any rate met with in common practise,* that is, from 10 cents to 25 cents per kilowatt hour, varying by increments of one cent. They may be obtained for either 2- or 3- wire single-phase circuits. The two-wire instruments are manufactured six styles for 50 or 100 volts and 5, 10 or 20 amperes. The three-wire instruments in three styles, for 100 volts and 5, 10 or 20 amperes. The counters in both two and three wire instruments record the exact amount of energy supplied to the circuit, and no multiplier or constant is necessary. This naturally simplifies their reading to the customer.

The Meters as Shipped. — The meters as shipped are arranged for a definite rate which the customer himself may change by ordering a new shaft on which the first counter is mounted. The kilowatt capacity or current and voltage marking of the meter and the rate per kilowatt hour must be given when ordering rate changing parts. The shaft can readily be taken out by removing an adjustable bracket from the back of the dial mechanism. The covers of all meters are sealed to guard against being tampered with.

Operating Principle. — The watt meters have been built from the beginning upon the principle of an induction motor, with a light rotating secondary whose speed is determined by the amount of current consumed upon the circuit into which it is connected. There has been an effort to obtain the highest possible ratio between torque and weight of secondary, in order that a light moving element might be employed and frictional effects upon the bearings minimized, giving a long lived efficiency and accuracy on light loads. The proportion of the windings and the form and construction of the electro-magnet have been calculated to reduce to an extremely small amount the energy consumed by the shunt and series windings. These basic principles have remained the same in the latest type watt meters and the improvements have been mainly in the manner of their application. There are several adjustments possible by loosening screws and moving them a trifle in a slot.

For instance, that of moving the magnets in from the edge of the disc will increase the speed, and moving them out will decrease the speed. By loosening two screws this is accomplished. Compensation for friction may be made by means of a screw as well. Another adjustment is that for alternations. Meters which are calibrated for circuits of 16,000 alternations per minute are so arranged that they may be changed to operation 7,200 by the movement of a screw in a slot. These adjustments for speed, friction and frequency are such as to make it elastic in its use on circuits. Much of this descriptive matter has been freely drawn from a bulletin issued by the Westinghouse Company on this subject.

Construction of Another Prepayment Meter. — The prepayment device employed by the General Electric Company consists of a Thomson recording watt meter with this addition attached to it. The original arrangement was that of a prepayment device and a watt meter separately perfected. The prepayment device is electrically connected to the meter, but mechanically independent. The ordinary type of Thomson recording watt meter is modified to suit this new purpose, but the meter which is used operates on the same principle and is identical excepting dial and cover. The dial is provided with a short-circuiting commutator which communicates with the prepayment device through a simple electric circuit. The prepayment mechanism consists of a simple rotating device which is normally locked, but can be unlocked by the introduction into the receiving slot of a coin of the proper denomination. When so unlocked, the handle of the prepayment device can be thrown so as to set the main wheel of the prepayment mechanism forward one notch. If the circuit be open when a coin is deposited, the same motion of the handle which sets forward the main wheel of the mechanism closes the circuit switch contained within the cast-iron box. A portion of the main wheel of the prepayment device is visible through the glazed aperture in front of the cover, and indicates in plain figures the number of coins remaining to the credit of the depositor. When the first coin is deposited, and the handle moved, closing the main switch, the figure 1 is brought into view. If a second coin is deposited before the current purchased with the first coin has been consumed, a second motion of the handle will bring the figure 2 into view. Twenty coins can thus be deposited consecutively. The prepayment meter has opened a large field in electric lighting especially where losses result from giving credit in many instances.

Classes Benefited by Prepayment Meters. — The careful watch of business by efficiency experts to-day is a feature of business life. The appliances to make business rapid, efficient and profitable are the telephone, typewriter, cash register and electric light. The motor might be included as an instrument of industrial progress. Prepayment meters actually apportion a certain amount of electrical energy to the motor or lights. If a business is divided into sections or departments, special meters would limit the power and lighting, or at least indicate the exact value of the power consumed. A cash business could thus have its accounts for power settled each day. Conversations with collectors of the cash of prepayment meters disclosed the fact that in many territories the business almost doubled through their installation. This being the case, it is evident that the following résumé will include those benefited by the use of such devices:

1. Families dependent upon each week's earnings for their livelihood and therefore safe in paying as they go.

2. Families careless in paying bills are forced by this system to either pay as they go or not have it; thus saving the company the need of useless losses in bookkeeping and collections.

3. People of means who are better satisfied with a system where they can pay without a collector calling.

4. Cash businesses where they are satisfied to have all bills paid each day or each week.

5. Merchants who use such meters in conjunction with window illumination, benefiting by its automatic quality of turning itself out after a certain amount of electrical energy has been consumed.

6. Factories, where power so figures in cost of production, that only a certain amount of power can be used.

7. The central station is benefited, as by its means missionary work is done in introducing the current.

8. Landlords find it pays them to have such meters, because no bills for light are unpaid and, therefore, the next tenant gets service.

Prepayment Meters as "Business Getters."—Business getting is partly due to personality and partly due to the need of the product. But the product is often dispensed with because it is not absolutely necessary. For instance a bright gas light is light enough for household use. It is displaced by an electric light, because for equal cost advantages are gained. Oxygen is not consumed, a noxious gas is not given off, the heat is less, the convenience is greater, no matches are used, the home is safer from fire, etc. But to bring these facts home the customer must be made to try the electric light. Often one light starts them off. It is placed in the kitchen with a prepayment meter attached. A few other lights follow because the lady of the house discovers the cheapness and convenience. An electric iron follows shortly. Then the rule is established, "That habit becomes second nature." It was the way with the telephone as it was with this. Homes accustomed to electricity find it has become indispensable.

In many households of modest wealth they have a horror of bills. Electric light bills are a mystery to some of them and the first trial is the hardest part. In towns of from ten to fifty thousand people, there are from two to ten thousand families to consider as possible customers. Roughly speaking, 10 per cent. are well off and 20 per cent. are moderately circumstanced. The balance, the 70 per cent., can use prepayment meters to advantage in their homes. The gas companies get business there and innumerable quarters as well. As tenants move out, no bills are left behind, the landlords are not bothered, and the new tenant has no meter to wait for.

In certain respects the central station can do a better and bigger business with the bulk of the community by installing prepayment meters than by other means. As to whether it would pay to volunteer to put a service and a few lights in homes on this basis is a question. In homes where people only rent by the month, it seems to be the landlord's business to supply the wiring. Central station managers can get after unwired houses of this type to advantage, for a large volume of untouched business can be had there by a man able to get it. All places rented by the week or month ought to have prepayment meters. In the course of time it is likely they will. The only question now is "When?"

CHAPTER XVI

LIGHT AND ITS COST

Light and Cost. — The question of light and its cost are natural and immediate, and may be regarded as of such importance that any means of reducing such cost to a fair degree is of public interest. But the cost of light produced by a central station is the pivot of the argument in any event, and the suggestions for cutting down this cost are all worth consideration unless examination proves the actual experiment unnecessary. Aside from experiments, the cost of light can be variously interpreted according to the contract made for the cost of current. That this charge may be larger or smaller, according to the amount consumed, is necessarily true. That it depends upon the character of the lamps employed is also to be understood. Then, again, the central station manager realizes that the operation of the station controls the cost of production, and that in this way also may be found an influence on the real proposition. Whatever the case may be and whatever the influences may be that determine the cost of light, the central station manager must have the power to control his expense so that a maximum is never reached in any instance.

Rates. — The cost of light received attention in the form of a paper on "Rates," read by Dr. John Hopkinson, F.R.S., in 1892, before the Junior Engineering Society of London. The idea growing at present in the public mind is that when money is paid out for current it is really spent for light. Were the proposition within the limits of practical solution at present it would not be a bad thing to sell light direct instead of the power which produces it. This, however, is a proposition a little in advance of modern practise. The question of the cost of current has taken its place and the difficulty is generally known as the Rate Problem. A prize of fifteen hundred dollars was offered for twenty-one solutions of the Rate Problem by the Central Station Development Company, of Cleveland, Ohio. In discussing the Rate Problem in their handbook they state as follows: "Dr. Hopkinson made it clear that the fundamental principles underlying any system of proper charging for electrical service and current required a fixed charge for the former and a charge per kilowatt for the latter. In 1900, Henry L. Doherty independently worked up the same thought, but carried it a bit further. Mr. Doherty pointed out that the fixed charge consisted of two components, one of which he called the customer's charge, which was the same for all customers; the other he called the demand charge, which, while not exactly the same for all customers, was essentially so, and was the same for all customers of given size and character." The Wright system of charging based upon the demand was widely adopted and rested upon the Hopkinson suggestion. Thus the Hopkinson, Wright and Doherty are the three systems in vogue in various forms. To quote again, "The Hopkinson, Doherty and Wright systems are not to-day receiving the consideration their merits warrant. All modern systems admit the fundamental points of the three former ones, although they are grievous compromises between the fundamental truths of these and the rate makers' conceptions of the public demands. In June, 1909, S. E. Doane, Chief Engineer of the National Electric Lamp Association, read a paper before the Canadian Electrical Association at Quebec. This paper is of importance to all central station managers, as it treats of the cost of light with authority and deep knowledge. It may be that some of our readers have been stimulated to write a prize winner on reading Mr. Doane's contribution, found in one of our issues.

Technics of Cost. — After the technics have been read and discussed and the ground thoroughly covered, the central station manager assumes a new position toward the problem. He holds the fort, as it were, against aggression, and is able to definitely state his views. There is much in this, more, in fact, than would be expected. The manager does not always know his ground and is often badly advised with disastrous results to his trade outside. When the science of charging is known as it should be, clearly, definitely and incontrovertibly — then the customer cannot complain if he is made to accede to the demands made upon him. Thus the cost of light becomes a problem with a business-like solution, instead of an arbitrary, indefinite and unknown quantity.

In the history of events little attention is paid to what are called minor circumstances; yet if human history were to be probed to the quick, it would be found that the events themselves are only the outward and visible signs of the apparently lesser things beneath. Thus, in the same manner, central station progress is not alone, because the machinery composing the plant has been perfected as we find it, but because a system was inaugurated on whose basis the plant was developed, and it is this, which is unseen, and to the layman unknown, which has led the way to such remarkable success as is now attained. The managers of stations cannot do better than pay the strictest attention to all papers that handle the Rate Problem.

Forms of Light. — There are many forms of light that might be used in homes were it not for the peculiar, if not artistic sense, the use of a yellowish flame, which has been from time immemorial developed, that makes a light of any other color seem bizarre in contrast.

Gas is cheap, but in its original form of flame seems most acceptable to those accustomed to old-fashioned lighting. The complaint sometimes uttered against the mazda or tungsten lamp is that it is too brilliant, but a glance at a new Welsbach will quickly alter the statement. Both tungsten and

Welsbach are brilliant centers of illumination, but when in use for a while, the Welsbach becomes less and less a form of habitual illumination, while the mazda or tungsten, undergoing no change that relieves it of its red rays, becomes more and more an agreeable source of light. Thus the argument narrows itself down to a question of the kind of light as well as the amount. Quality not quantity. Red rays in lieu of those that render a light cold and unfamiliar to the eye. Consider cost from this standpoint, and the well balanced mind sees a new point of view. The idea is that of the purchase of a thing desired. Only one form of electric lighting is regarded as unfit for home use and that is the mercury-vapor lamp. Here the red rays are so excluded that the fact is pronounced at first glance. Light is produced plentifully and cheaply, but who cares to sit in a light that renders the countenance livid and the normal color of things anomalous and surprising. Yet this light has great uses in factories and on docks and in places where household objections from feminine lips have no place. Therefore, cost can only be considered when the right thing is used and not when a question arises as to the color of the light.

Tungsten versus Welsbach. — Central stations sell power, but the consumer really expects them to sell light. Gas varies in price from eighty cents to a dollar and a quarter a thousand. Burning a thousand feet of gas will give two five-foot gas jets light from five to ten P.M. for twenty nights, or two five-foot jets for about three hours a night for a month. If Welsbach mantles are used the light will be increased, but the mantle wear and tear must be considered. On the gas jet basis thirty-two candle-power is obtained for three hours a night for a month, at a cost of eighty cents. On the Welsbach mantle basis, fifty candle-power can be obtained for a while with a five- or seven-foot consumption per hour per mantle for two hundred hours or proportionately less, according to the consumption per hour. But allowing a ten-foot consumption per hour and a Welsbach candle light of seventy-five candle power as the result, the accumulated and total light would be 75×200, or 15,000 candle hours for eighty cents, or a dollar or more in cities charging a higher rate.

A mazda or tungsten lamp of one and a quarter watts per candle-power would mean the development of one candle-power for every one and a quarter watts consumed. The consumption of one thousand watts would mean the development of eight hundred candle-power. A thousand watts costs ten cents, so it is evident that for eighty cents the candle-power obtained is 8×800, or 6,400 candle hours. If the rate is less than ten cents per thousand watts, the candle hours naturally increase.

Fair Comparison. — No gas man could complain of the handicap purposely given in this case to elucidate the principle to follow. Gas can give light very cheaply by means of the rare oxide mantle. But it is not this which has given the mazda or tungsten such prominence and defied competition. It is the fact that while one thousand cubic feet of gas with new Welsbach mantles will give a light even greater than that recorded, it cannot be depended upon to retain either its candle-power or color after a given period has passed. Therefore the quantity as well as the quality of light changes and the 15,000 candle hours for eighty cents the first month falls away the second and third month, until the realization of the change becomes apparent to even the casual observer.

To come to such a conclusion oneself it is only necessary to gaze steadily at a Welsbach of a month or two's age for a few moments and then turn the eyes suddenly to a tungsten lamp nearby. The impression created is that of an unusual quantity of red light in the incandescent lamp and a greenish tinge in the Welsbach. The reason is that there is an absence of red rays in the Welsbach light, and the eyes, shifting suddenly to the tungsten while hungerering for red rays, finds them and discerns the difference in the quality of light.

In homes where economy is the watchword, the Welsbach has had and is having its day. The fragility of mantles need not be mentioned, as the same trouble more or less affects the tungsten filament, but economy cannot be practiced when the thing purchased is not wanted. A disagreeable or changing light cannot be cheap. It is always dear, even though it be given first place in this respect in comparison with any other form of light.

Electricity has become a public commodity, and the central station in large cities a public servant. Considering its huge investment and the comparative newness of its installation, the absolute cost of current will only be deduced when certain financial considerations have been well settled. With increasing use on an enormous scale prices gradually go down until a point is reached satisfactory to all concerned. Yet conservatism must rule, and for that reason the future consumers of electricity are the now unknown millions, whose influence on the cost of all things will be quite sufficient to obtain it at a price which will make any question of the cost of electric lighting seem choice satire.

Economy in Station Practise. — Economy in station practise is the watchword to success, and its best exemplification is found in the regulation of voltage in cases where the lighting company supply the lamps for nothing. The next example of economy in station practise is in handling of the coal, not only as regards its purchase, but its subsequent spreading on the fire by automatic or hand power. Thus, fuel and filaments are the two propositions that hold the interest of economists and students of central station methods.

The introduction and success of bi-metallic and tungsten filaments has made the need of care more than ever imperative as the costliness of the lamp has increased; and whether the lamps are carbon and supplied free, or tungsten or tantalum and paid for by the customer, the station regulation must be carefully watched to hold the voltage to its proper value as an economical operating pressure.

In treating this subject, the writer has previously stated: The importance of considering in its proper aspect the light of lamps of the incandescent type, is due to the relationship between voltage and candle-power in these lamps. To obtain the maximum light from the minimum power is not so much an object as to obtain durability or lasting qualities in the lamp. As lamps grow old they deteriorate and the light grows dim, so that to obtain the correct candle-power such an accession of power is required as to make the production of such light a most uneconomical proceeding. The efficiency of a lamp or the relation between the light it gives and power it consumes, are matters of the utmost importance not only in its construction, but in its utilization as well. In speaking of power, both volts and amperes must be considered, therefore, when greater or less voltage is supplied to lamps or when the percentage of the normal is below or above 100 per cent., the power consumption and the candle-power vary accordingly. Tables have been prepared by manufacturers covering these features, but they generally relate to the ratio of candle-power to watts.

Loss in Low Voltage. — A lamp lasts much longer if the voltage is a little lower than that at which it is rated. But the difficulty lies in the voltage being too low and the light too dim. In other words, a slight reduction in voltage to the lamp means a great drop in candle-power, and if ten to twenty thousand dollars or more are spent to obtain a certain amount of candle-power, and twenty-five per cent. is wasted by low pressure, the remaining candle-power is obtained at a heavy expense. The only item to counterbalance this is the saving in lamp cost. The saving in lamps must, therefore, be balanced up against the value of the light on such a basis. In all probability a twenty-five per cent. cut in candle-power will not pay when compared with the saving in lamp renewals. The amount of coal lost in the way of light wasted costs more than the lamps saved.

In one hasty calculation made, it was found that in a case where the candle-power of the plant was down nearly twenty-five per cent., of the $1,200 worth of coal annually purchased, about $300 worth was being systematically thrown away by the drop in candle-power. The idea, of course, is that practically the same amount of coal must be used whether the voltage is down a few per cent. or not, but if the voltage is down a few per cent., the light is cut down a considerable percentage. Therefore, the point involved is this: that it does not pay to run at low voltage because no coal can be saved and from ten to twenty-five per cent. of the light is wasted.

On the other hand, if the low voltage is due to the attempts to save lamps from deterioration, an inquiry in this direction will quickly show whether the dollars saved there equal the dollars wasted as shown in coal. In this calculation referred to it was shown that only $200 worth of lamps were saved per annum. The lamp renewals would have been three a year instead of two, but the use of low voltage saved the lamps so that the renewals were cut down from three to two per annum. Now each lamp renewal cost $200, therefore, instead of $600 being spent, only $400 was required for new lamps each year, a saving of $200 resulting thereby. But it must be remembered that the coal wasted, from which no good whatsoever arose in the way of candle-power, was worth $300; therefore, the case as it stands is one in which $300 was wasted to save $200 in lamps. It must be understood, however, that the cost of the coal purchased will affect this conclusion, for if the coal is cheaper, then the difference becomes less. In the case of a water-power plant, where the cost of the power, in an actual sense, is the interest on the investment made to utilize it, the cost may be very low. It might pay, if the customers will stand for it, to run at a lower voltage.

But such economy is false and inimical to the best interests of the business at hand. People who wire their places and depend upon electricity for light, really feel that they are purchasing light and electricity. The practise to-day gives them a better chance than ever before to get light cheaply, yet their bills and fears are still matters that the auditing or adjudicating departments of central stations have to contend with. Until they get so much more light than they need for a small sum, as they do water from the city mains, complaints are to be expected. Yet much of the error of thought and a considerable part of the complaint, is being eradicated by the thoroughness of the educational system that has been and is being promulgated by the publicity departments of up-to-date central stations.

Cost of Publicity. — The common practise is to consider the technical expenses of the central station when referring to the cost of current, whereas other elements enter into a consideration of this problem; namely, the relationship of cost to rates. In new and growing territory the publicity department of a central station is frequently taxed to its highest point of efficiency in rendering service to the central station. The financial cost of an active, aggressive, and efficient publicity campaign is an item which enters seriously into the total cost of the operation of the station. The Rate Problem is therefore in its essence one which depends upon the Cost Problem, and the Cost Problem in its turn is composed of a variety of elements which regulate prices.

From a fundamental point of view, the earnings of a company are part of the cost, for the simple reason that the entire operation of the organization is directed to that end. In other words, the cost of operation, plus the profit, is a measure of the excellence of operation.

CHAPTER XVII

EFFICIENCIES IN ELECTRIC LIGHTING

Thirty Years Ago. — Three decades, thirty years ago, electric lighting was in its infancy. It is hardly a generation ago, yet the world, the world of city-life, has been transformed by it. Its influence has not ended there, for in the outskirts, the suburbs, it holds the winning hand. And between suburbs, stretching mile after mile through the darkness, along the old country road, the electric light is master of the situation. The hard-blowing wind cannot put it out, nor can the storms of wind or snow destroy its usefulness.

Beginning with 125 horse-power and 400 lamps, the central station industry was initiated in New York City. It has grown a little since then. At present there are 5,000,000 lamps in use, exclusive of 40,000 arcs. There are motors in New York, on central station circuits, that consume 400,000 horse-power. The sub-stations, main stations, and all complete represent a development of 700,000 horse-power.

It will not be long before New York City will require a million horse-power to supply the patrons of the central station mains. A million horse-power is a prodigious amount of energy. Think of this concentration of power, and that it means that only the surface of application has been scratched, so to speak. The industries in New York City are there because it is the best place at present for them to do business in. But they will not be there always. Industries cluster where fuel is cheap, where shipping is available, and where the markets are at one's elbow. When it is found impossible to place the industry where the power to operate it is found, the electrical engineer till further solves the problem. The world is full of such examples. He generates electricity and transmits it.

Transmission. — Marcel Deprez in 1881 showed the case and certainty of transmitting electricity over a wire for purposes of power. Its use for transportation was also considered and now, side by side, the transmission and transportation systems threaten to girdle the civilized world. From out-of-the-way rocky fastnesses, where mountain streams leap precipitous heights, power is led to human communities to do the day's work. In transportation the electric road has linked town to town. The energy employed has risen from 90 volts to 11,000, and the efficiency has so increased that for miles away from the central termini the electric zone predominates.

The statistician has presented figures to the interested which show a marvelous increase in wealth as the result of the crystallization of these ideas and the establishment of these systems. The lowest estimate places the capital involved in electric light and power projects at a billion dollars. One thousand millions as the result of the invention of the electric light and motor, and double or triple this amount when electricity becomes more universally employed. There is something to think of in the army of workmen required, the contiguous industries, the direct advantages to civilization resulting, and the leaps and bounds of an irresistible progress. After all, three decades of lighting have brought some compensation to the public and the investor. Though the first ten years were experimental and the path thorny, the fruits of effort are now visible, and those whose courage led them to risk capital have had their reward.

The three decades of lighting and power development might easily be divided into the three, so far, important chapters of central station history. When De Meritans built his first dynamo with permanent magnets and lit electric lamps, the experimental stage was being passed through. Only proof of the possibility was thus manifested. Then followed the actual utilization of the arc and incandescent lamp, and finally the employment on a large scale of these ideas.

The first decade of the industry was therefore very experimental at its best, with frequent changes in machinery. The second decade was noteworthy through the more definite establishment of the system and the burying of all wires underground. The fact that there was a D. C. and an A. C. system lined up against each other was forgotten. These two systems began to blend together. The direct current found its limitations, and the further development of the enterprise demanded the use of alternating for the purpose of extending the territory. Therefore, the first stage or decade was one in which direct current was exclusively used, with wires overhead and a very limited zone of actual operation. It might be best called the stage of concentration. The second decade was noteworthy by the fact that the use of alternating current was found necessary. Wires were put underground. The generators and engines were slowed down in speed. The engines were made vertical, and the Van Vleck marine system prevailed. The first and second decades were thus mobile stages of growth and change, with marked features of expansion.

Extending the Zone. — The use of alternating current for the purpose of extending the zone of operations, the use of direct current in a non-dangerous form in the house, and the invention of a new lamp, the tungsten filament, led to many marked changes. These initiated the third decade of electric lighting, in New York particularly, but also in other cities. The third decade still retained features which showed the experimental stage had not passed, but it was, and is now, marked as it might be best known — the stage of exploitation. Never in the history of electricity has its exploitation reached such a degree of intensity. The reason for this is not psychological, but strictly commercial. Where formerly it has been known only in an experimental form, it became established and received recognition as a commercial commodity for which a demand has been widespread. Thus the idealistic dream of Faraday, Ampere, Ohm, Joule, Edison, Swan, Gramme, and a host of other experimenters, mathematicians, mechanicians and pioneers of theory became reality. The old problems have been almost forgotten, the new ones have crowded them away so rapidly. The fear is not that electric lighting will ever be other than a success, but that the onrush and press of new inventions will stamp and change our new, efficient and wonderfully fine system of to-day into a back number.

Who is the prophet who will dare to cast a horoscope of the future? The substantial methods of to-day seem so real that it does not seem possible they can ever become ancient. Yet the way of the scientist is full of surprises, and as the Marconi invention has made it unnecessary to bridge the ocean with a substantial cable, to fling from shore to shore the news of the day, so some surprise may be awaiting the generation still unborn of equally stupendous importance.

The three decades of electric lighting, however, are now ended, and the fourth is but beginning. It is very likely from present indications that the new decade will have two features of importance to disclose: First, the more positive crystallization of the present system of lighting and power transmission and distribution; and second, the still further development of the incandescent lamp until it reaches eventually an unpassable efficiency. If three decades have stamped this as the most wonderful age in the history of man, the promise the coming decade extends ought to fill us all with the happiest auguries of the future.

Efficiency in the Boiler Room. — With a modern plant, efficiency is like the earnings, an expected thing. But the up-to-date, modern manager has more than machinery to bother him. The thing in his mind is success, and gaining it is his problem. There are two definitions of success: One, accomplishing what you have in view; the other, making money. The artist's success differs from the manager's. He must make money. It is not his money that he makes, but other people's; yet, if he does not make it, he loses his own. He can make money in two ways: Outside the central station and inside it. Outside in getting business; inside, in preventing waste. The manager must be a many-sided man. His brain must be suited to business, the getting of it; he must be a salesman, a manager and engineer, and a diplomat — incidentally, a financier. To prevent waste inside the station, there is labor, fuel and time to consider. The labor one can see, at least the results of it. The time spent in doing things can also be supervised and accounted for. The problem in many cases is the fuel. Getting as much out of it as is there and trying to use it.

Burning the Coal. — Coal, as ordinarily burned, gives up its heat units, as one engineer said, mainly to the chimney. But a good manager wants it to give up its units to himself. To accomplish this, various methods are employed. Economizers are one, mechanical drafts are another, automatic stokers are a good third. Heating the feed water with the smoke-flue or chimney heat, or by means of the exhaust steam, is old but reliable. Getting the coal entirely consumed is another method done by means of the mechanical draft.

When a molecule of coal-carbon — to be scientific — is entirely and thoroughly surrounded by live oxygen, a combination takes place. The combination results in heat, flame, the development of carbonic oxide and the disappearance of both. Were every particle of coal absolutely consumed in the fire there would be no smoke, no soot and no waste on that score. All the heat units would be liberated and it would be our business to get them. We would get them more effectively than at present. To do this the use of an artificial draft is recommended in cases where results are now missing.

Efficiency in Germany. — In Germany they have boilers and steam engines combined, called lokomobiles, in which for every pound and a half or two hour pounds of coal, a horse-power is produced — in small engines, too. Efficiency in the boiler is the thing there. The use of superheated steam is the other feature. When the steam is generated in the boiler proper, it is led through pipes into the flue again and there raised in temperature. Two cylinders are employed to extract the power. The first gets the hotter steam, the second the exhaust from the first. Waste is cut down, the heat is fully used, and a general economy results. A special construction is required for this; but at least we of the western world can burn our coal, control its combustion, and even use an inferior grade, if we wish, by using the forced draft in plants large enough and otherwise suffering from a plethora of fuel and yielding a niggardly return in power.

Utilizing Waste Heat. — The best of central station economists agree in the belief that waste heat is the death of dividends. The saving or utilization of waste heat in any enterprise whatsoever is the best possible evidence that common sense has been freely employed to establish a business basis. Now business means two things; it means exchange and profit. The idea of exchange is buying and selling. The idea of profit, is gain above all expenses. Business in central station service means the stopping of losses, and the encouragement of gains. Waste heat is a loss, because coal is burned to produce it, and coal means money; and although the waste heat is invisible, the sensation of discovering it on the books at the end of the year, in the way of dollars gone, is bad business.

Heat is wasted in steam plants, and in gas-engine generating equipments. Heat is an irregular or unsystematic form of vibration. It is in many ways a crude form of energy. Its conduction is not done with any reasonable efficiency: and in those forms of mechanism which produce radiation of an extensive character, the loss is quite marked. This applies to the steam and gas engine. The tendency to save or to utilize heat and turn it to some useful purpose or into money, is now a marked feature of business economy. As stated in an article on the gas-engine's waste heat to mark a specific instance: "With a 100-horse-power engine running at full load, and a heater of six cubic feet gas capacity, we are able to make available 600,000 B. t. u. per hour, stored in water at a temperature of 210 degrees. This would be sufficient to warm a work-shop of moderate size in ordinary winter weather, or useful for any manufacturing operations requiring such a moderate temperature as 200 degrees or under, but the conditions must obviously be especially favorable in order to turn to account the waste heat. The available quantity of water per hour (4,000 pounds or 480 gallons) is a mere bagatelle in most cases where hot water is used industrially. Moreover these figures are based on full-load operation, which usually covers only a small part of each day." The general radiation of heat in all cases where heat engines are employed, is one of the features of that class of mechanism.

This is true of the ordinary grate fire, the kitchen stove, the hot-air system employed to warm houses, hot-water and steam radiator systems as far as homes and factories are concerned; and emphatically true of gas and steam engines and their appliances as far as power-producing devices are concerned. All of this means a waste of power as well as a waste of fuel. It not only means a waste of fuel, but something infinitely worse, the reduction permanently of the only material that is generally used to produce heat and power, namely, coal. Various authorities have passed opinions on this subject, but whatever their opinions have been, they have but little effect in alarming the world to a sense of the economy necessary in order to avoid a fuel famine at some future date.

The use of asbestos to reduce radiation in the case of steam machinery is but part of the attempted solution of this problem. The greatest loss is in the chimney employed to produce a draught. This is the source of enormous quantities of waste heat and in consequence wasted fuel.

Heat Energy Limited. — Sir William Ramsay, the distinguished English chemist of international fame, in an address made before the British Association, composed of the greatest scientists of England, has this to say in connection with the fuel problem: "We have in this world of ours only a limited supply of stored-up energy. The rate at which this supply is being exhausted has been increasing very steadily for the past forty years. It is easy to calculate that in Great Britain, if the rate of working increases as it is doing, our coal will be completely exhausted in 175 years. In the life of a nation 175 years is a span. Attention has been repeatedly drawn to the enormous quantity of energy stored up in radium and its descendants. Suppose that the energy in a ton of radium could be utilized in thirty years, instead of being evolved at its invariable slow rate of 1,760 years for half disintegration, it would suffice to propel a ship of 15,000 tons with 15,000 horse-power at the rate of 15 knots an hour for thirty years — practically the lifetime of the ship. To do this actually requires a million and a half tons of coal. It is easily seen that the virtue of the energy of radium consists in the small weight in which it is contained; in other words the radium energy is in an enormously concentrated form. If we know for certain that radium and its descendants decompose spontaneously evolving energy, why should not other more stable elements decompose? This leads to the speculation whether, if elements are capable of disintegration, the world may not have at its disposal a hitherto unsuspected source of energy. If radium were to evolve its stored-up energy at the same rate that gun cotton does we should have an undreamed of explosive; could we control the rate, we should have a useful and potent source of energy.

Other Heat Sources. — "If, however, the elements which we have been used to consider as permanent are capable of changing with evolution of energy, if some form of catalyses could be discovered, which would usefully increase their almost inconceivably slow rate of change, then it is not too much to say that the whole future of our race could be altered. It would be impracticable in the northern countries to attempt to utilize terrestrial heat from bore holes; others have deducted that from the winds, the tides and water-power. Small supplies of energy are no doubt obtainable but in comparison with that derived from combustion of coal they are negligible. Nothing is to be hoped for from the direct utilization of solar heat in this temperate and uncertain climate, and it would be folly to consider seriously a possible supply of energy in a conceivable acceleration of the liberation of energy of atomic change. It looks utterly improbable, too, that we shall ever be able to utilize the energy due to the revolution of the earth on her axis, or to her proper motion around the sun. We must save our coal and our forests. Every nation must at once take up this problem. At least this will give us more time to meet the threat of the powerless era now dawning on us."

Saving Waste Heat. — It seems highly appropriate in conjunction with the consideration of a means of saving waste heat that the conditions pertaining to our fuel be reviewed. Saving waste heat means the saving of fuel. Saving fuel means the postponement of an impending crisis in industrialism. Central-station managers are taught to save fuel as well as to save heat. The first lesson in the school of economy is to economize. This means stopping station leaks. It means saving coal. It means having heat that would be otherwise wasted by utilizing it. Fuel economizers and improvements in combustion and chimneys are in order. It is likely that the future is not quite as dark as painted by Sir William Ramsay. Yet the lesson taught after all is economy. Heat that can be used must not be wasted.

CHAPTER XVIII

THE GENERAL DISTRIBUTION OF LIGHT

Street Lights. — The purpose of street lights is to gain an even and effective distribution of the light for purposes which may be readily understood and enumerated. Primarily, the purpose is to obtain sufficient illumination to make travel safe; secondarily the purpose is to give commercial value to the street or streets by illuminating the shops or show places. On the other hand, street lights serve a set of purposes which may be stated as follows:

1. To supply sufficient light to make travel safe during the night.

2. To brighten thoroughfares possessing a high commercial value on account of the stores which invite night traffic.

3. To indicate the main arteries of city life most occupied at night.

4. To reduce or eliminate crime, such crime as is encouraged by darkness. The old system being one in which stores were kept dark, the new one keeps them well lit.

5. Bright street lighting acts as an advertisement to the storekeeper, not so much by lighting his windows as by attracting the crowd to that section. Other reasons may be given, but safety, conve-

nience and business advantage are the three of leading importance.

Getting a certain candle-power per square yard or per square foot is really one of the chief objective points. To secure results in cities or towns it is customary to use one or all of three things: Gas, incandescent lights and arc lights. Experience is the guide in all cases, and seems to show conclusively that electricity is the most economical and most satisfactory to use. This was not an opinion derived from a cursory glance of the situation. The gas companies fought for the control of street lighting for many years. They eventually operated small additions of their own in the way of electric lighting. The result, in the course of two decades of trial, justified expectations in favor of street lighting by electricity. The reason for this conclusion is entirely due to the facilities it supplies for superior illumination and the easy and certain control of that illumination. Were it possible for the gas-light companies to devise and operate a means of practically controlling the lighting of the lamps either in groups or singly from a central point, then the comparison of ease of operation would not fail, as it does now. But electric lighting spells control, as well as it spells brilliant and efficient illumination. For that reason, not only has the economic factor enabled it to win supremacy in the field of general lighting, but the fact that one or all lights are susceptible of easy and simple control.

Degree of Illumination. How brightly shall streets be illuminated is a pertinent and practical question. The degree of illumination has far-reaching effects in many respects. The cost of a lighting system or the manner of lighting a large city is not wholly found in the bills for gas or electricity. There is more than this to the problem. It is also found in the cost of renewals or renovation. Every large city has a past history of system after system being installed and removed. The effort represented in each case was to attain a certain degree of illumination with a measurable degree of economy. Now that economy dictates the use of electricity, the question arising is that of the particular stage of brightness most practical to employ.

There are two horns to the dilemma, as the saying goes. If the centers of illumination are too bright the effect is bad upon the eyes and nerves. Therefore, they must be either so placed as to shield the observer or pedestrian from the glare, or protect him by the employment of opalescent or ground-glass globes. The other method is to have a great number of lights of less individual brilliancy so scattered that the general illumination is sufficient without any undue glare. When Brush invented his arc, the custom with the original type was to support them at the top of high poles at street corners, and thus light the block or street from corner to corner.

Amperes	Volts	Watts	
10	55	550	....
10	80	800	....
10	60	600	....

An objection to bright street lighting is found in the complaints of some residents, that either the light of the arc shines directly into their rooms, or the general brightness affects their sleep sufficiently to become a nuisance unless the blinds are closely pulled. This shuts off the air supply, and affects the hygiene of otherwise perfectly tolerable surroundings. The necessity, however, is marked for bright street lighting, and the arrangement of the shutters or blinds must be such as to adequately meet this condition.

To be able to read in any part of a street at night seems almost too much to expect; yet the light of Fifth avenue or Madison avenue, New York, is sufficient to permit this to be done. These streets are well lighted; in fact, the best lighted in the city. For that reason, if one were asked: "What is the best degree of illumination to employ?" the answer would be the amount of light that accomplishes this object. On the other hand, it is evident that a city can waste great sums of money by having the streets too light. This is as bad as having them too dim. The only way out of the difficulty is to have a commission able to interpret public opinion, and secure what it demands and needs.

Needs of Interior Lighting. — The home, factory, business house, store and theatre each make very different demands for correct and efficient lighting. The home needs a subdued, mellow light. It must not be too brilliant, nor must there be too much of it. The factory requires plenty of light, concentrated where needed and convenient to handle. The business house requires lights sufficiently high up to illuminate goods, show differences in shades and quality, and give a cheerful impression. The store needs window lighting and interior lighting. The window lighting is generally best done with incandescents. The store is best lit with arcs and incandescents. In theatres and public halls and buildings the illumination is more or less artistic, and unique effects are aimed at and secured. The architect or interior decorator is largely responsible for the general result obtained, but the rule seems to be not too much light, only enough to read without undue brightness. The recent hygienic development in the home, factory and city life has left its mark in the way of lighting as well. Factory requirements are such to-day that not only fresh air but light is a legal necessity. Interior lighting thus represents a phase in the evolution of central station practise of a noteworthy character. It covers a variety of features not the least among which are the following:

1. Sufficient light to avoid the suspicion of darkness in corners.

2. The shading or toning of light to prevent the effect of glare or intensity.

3. The use of light rays, which do not change the color of room contents.

4. Sufficient small centers of light to produce light effects wherever desired.

5. Tendency to hide the source of the light from

the eye and create only general illuminative effects by placing lights in cornices or ceiling reflectors.

For floor lighting a rate per square foot is easy to obtain. Authorities differ in this respect, but an allowance of one 16 c. p. lamp per 50 square feet for the floor seems sufficient, and an allowance of 100 square feet per 16 c. p. for walls seems satisfactory in all homes. The glass employed for globes or chandeliers needs consideration in the following form:

Character of Glass	*Per cent. of Wasted Light*
Ordinary pane glass	about 10
Cut or pressed glass	from 10 to 15
Ground glass	from 25 to 40
Opalescent glass	from 25 to 50
Red glass	from 30 to 60
Blue glass	from 15 to 30

This degree of absorption is an object lesson in general electric lighting.

Getting the Light Through Different Globes.— Distributing light properly is an interesting problem in science as well as general practise. For instance, great care may be used in selecting efficient lights, yet the advantage of their economy may be lost due to inferior judgment in the selection of globes. The various types of shades and globes govern the amount of effective candle-power obtained. It is a well-known physical fact that the various colors of glass are more or less absorptive and may reduce the amount of useful light to such a degree as to render useless efforts to better it. The depth of color in the glass is a prime factor in determining the degree of absorption. A great deal of candle-power can be produced and wasted by the use of poor globes, thus nullifying advantages of good wiring and regulation. In choosing globes several points must be taken into consideration which might be tabulated in the following manner as far as general features to be considered may be concerned.

1. Cost of globes. The value of a globe is apt to be considered in contract jobs.

2. Diffusion of light. The degree to which this happens is regulated by requirements.

3. Degree of absorption. This is the manner in which good light is aften wasted.

4. Artistic design. The artistic taste of the owner is the influence acting here.

5. Fragility. Expense may be greatly increased through the fracture of globes.

By the use of a little common sense the selection of such important articles may be made with a definite purpose in view. Many of the best looking globes are poor light transmitters and the converse. As a general rule the cost and design are the predominating factors, whereas the effective diffusing of the light and the degree of absorption are perhaps of more importance from an economical and practical standpoint in the long run.

It is evident that the distribution of the light is of more importance than the quantity, and a great deal of power can be effectively wasted to light a room, where one-half as much consumed in properly arranged lights, would give greater satisfaction.

The absorption power of the globes must be considered in practical lighting, particularly where it is necessary to bring out decorative effects at night. If the general tone produced by the decorators' art in fine apartments is blue, pink or red, the lighting must be done by choosing positions and globes to augment this effect and not to produce a disagreeable impression through inattention to such details. If red, blue or other colored globes are employed and full illumination is required, the lost percentage of light must be added in the number of lamps or the candle-power of the globes.

The great dry goods and department stores, the public buildings, the theatres, the churches and the home, — these are not easy problems that relate alone to the putting in of wires. They call for greater knowledge, which in its highest form goes hand in hand with the dictates of art and fashion. To produce not merely light, but a uniform light, is the main idea, and in great auditoriums a careful study of conditions is the only way of meeting with any degree of success.

CHAPTER XIX

SCIENTIFIC LIGHTING OF CITY STREETS

Few Lights of High Candle-power. — The old system was to use few lights of high candle-power and thus light the streets. The lights were originally placed high in the air on tall poles and were very brilliant. The lighting done in this manner was more sensational than effective. The predominant characteristic was glare, which though representing plenty of light, also meant plenty of wasted light. As one writer states: "In many street lighting installations the light sources are so brilliant that they dazzle the eye and produce a blinding effect, which not only interferes with seeing, but may be actually injurious. For instance, when a light ray of high intensity directly enters the field of vision the resulting glare causes an involuntary contraction of the pupil of the eye, so that objects can be less clearly discerned than with a smaller amount of light and no glare."

Angle of the Greatest Illumination. — Every light has its angle of greatest illumination. This is true of the burning pine-torch, the wax-taper, the kerosene lamp, the gas jet and the incandescent and arc lamp. What must be discovered by test, with any new or old light, is the angle at which it throws out its greatest quantity of light waves. On account of this distinction between amount of light in total, and angle at which the greatest light is thrown out, light sources of different types have their peculiarities. It is a simple matter to test the effect with a candle, oil, gas and incandescent lamp. The shadows cast in each case will be different. Photometer tests would show a great range of candle-power at different angles. And it therefore becomes necessary in studying a lighting problem, to discover whether the light is to be thrown down, up or sideways and at what angle. "If the maximum candle-power should be nearer the horizontal, too much of the light would be wasted on the sides of the buildings or trees, while if the maximum candle-power should be nearer the vertical, too great an intensity of light would be concentrated under the lamp. In order to secure the desired illumination at the points midway between the lamps the maximum candle-power should be given off at an angle varying from 10 to 30 degrees below the horizontal."

In lighting a street it is not necessary to cling to only one type of lamp. That is to say, because arcs have been almost exclusively used in the past in large cities does not mean that they will always be employed. The idea is that the street must be well lit. To light it well, incandescent lamps are just as practical as arc lamps. There are two questions to consider, however, before a choice is made: First, will it cost more or less with one kind of lights or the other? Second, what will the rate of deterioration be with one as compared with the other? This would include renewals, labor, risk and repairs. The premise being that the effectiveness of the lighting is the same in either case, while arcs have the advantage of intensity and a lower wattage per candle-power, at the same time they need care, renewals and adjustment. Incandescents on the other hand give less light for the same power consumption. But they do not need the same care, cost less in labor and need no adjustment. A balancing up of these two sets of features reduces the problem down to a consideration of efficiency and light production. By efficiency is meant the cost of producing a thousand candle-power in one way or the other. By light-production is meant the consideration of the amount of light that must be commercially produced to make the lighting project worthy of entertainment. Where struggling country districts are to be electrically lit, there seems to be but little choice as practise shows them to install the incandescent lamp. In crowded thoroughfares, where plenty of light is needed, and the street must be bright enough to enable one to read a newspaper with ease at night, the arc seems to be the accustomed means of solving the problem.

Glare. — In lighting streets the other side of the problem is to avoid glare. In this nervous age, everyone is to some degree hypersensitive. Noises bother one class of over-strung people, colors another and glare still another. One writer believes in the settling of the difficulty in this manner: "To minimize glare, we must either prevent the light rays from entering the eye directly, or choose an illuminant of a relatively low intrinsic brilliancy. The former remedy is not always practicable in street lighting as it requires an excessively high suspension of the unit. We must, therefore, adopt the latter method, and instead of the large candle-power units, with their particularly high intrinsic brilliancy, use relatively small units placed reasonably high, or at the side of the street."

It is evident that the hygiene of lighting has come into existence. It must be considered from a physical and psychological standpoint as well as that of strict utility. "Where formerly the success of a street lighting installation was often judged by the brightness of the units, now, with the increased knowledge of the purpose of street lighting, the determining factors are the amount and distribution of light upon the street. The scientific and economical aspects of the problems connected with the proper and artistic illumination of the streets are daily receiving increased attention. From the evidence thus far supplied it becomes apparent that glare is not due to excessive light, but the angle of the rays with reference to the eye. It is also obvious, that our present light-producing mechanism capable of creating immense quantities of light is more or less subject to this defect. Consequently, wherever powerful arcs are used for street lighting, a heavy waste of light ensues, because of the glare-protecting but inefficient globes employed. If 40 per cent. of the light is thus absorbed and wasted, it is evident that though the system of production be efficient, the system of light distribution is woefully deficient. This is not the fault of experts, neither is it due to carelessness. It is simply the organic defect in the best system extant for the successful illumination of streets.

Amount of Light Required for Safety. — In crowded thoroughfares like City Hall, Union Square, Madison Square, Herald Square, Times Square and the Circle in New York, or the Strand in London, or any other well-known business center, a great amount of light is required at night for safety. The vehicles are innumerable and the people are often massed. "The actual intensity of light required for safe traveling varies with the amount of traffic on the street. If the traffic is heavy and liable to become congested, a large amount of light should be supplied so that all obstructions can be perceived at a glance. To escape being run over or to avoid collisions, quick decision is often necessary, and accordingly there should be sufficient light on the street so that the easiest and safest path can be instantly detected. In other places where the travel is not so dense, the danger of collision is reduced and less light will be found satisfactory." The amount of light required for safety is, therefore, best judged by the particular place to be thus protected by illumination. A certain candle-power per square foot of street surface is required at night at all events. But when there is moonlight the street lighting could be reduced, but the municipal contract forbids it. These contracts so read, that during certain hours, times and days, a certain number of lamps of a certain candle-power must be lit, moonlight or no moonlight. With moonlight the shadows are deep and the only way to dispel them is to have a uniform light.

Uniform Illumination in Streets. — To get light of equal candle-power in all places is a difficult problem. It means regulating the light so that extremes are avoided. One way is to place the lamps near enough to avoid heavy shades between. Another way is to diffuse the light artificially by increasing the number of rays but decreasing the intensity of the rays. Still another way is to use many lights of relatively low brilliancy. On this subject one writer speaks very clearly, "Uniform illumination, however, is a quality which every street lighting installation should possess, and to which too much importance cannot be attached. We do not mean that there should not be the slightest variation in intensity, over the entire street surface, but we do mean that there should not be a great variation between the maximum intensity near the lamps and the minimum intensity midway between. The allowable variation has been given as 10 to 1, and though this value cannot always be attained in practise yet it can often be closely approximated. If the variation in intensity is allowed to become much greater the danger of accidents occurring in the shaded places is unnecessarily great. In fact the gloom in these dark portions of the street is apparently very much deepened by contrast with the adjacent light portions, and consequently greater caution should be exercised. It is readily perceived that a large amount of light concentrated at one point is not nearly as effective in lighting a street as the same total amount of light distributed among several points along the street. If this idea is carried to its logical conclusion, the importance of uniform illumination attained by small units and frequent spacing must inevitably be acknowledged. In fact, a smaller amount of light uniformly distributed affords better illumination and safer travel than a large amount of light unevenly distributed. In other words, the actual intensity of light used need not be high if the distribution is uniform. Therefore, in designing a street lighting installation a great deal of attention should be paid, first, to the size of the units so as to secure a sufficient amount of light; second, to the characteristics of the illuminant, its height, spacing, equipment, etc., so as to secure a reasonably uniform distribution." Thus, the proportion is summed up and the conclusion again reached, that sufficient light must be produced all over the area to enable drivers and pedestrians to see clearly. Neither intensity nor quantity are the ruling factors, but uniformity and quality. Whatever is done in effectively diffusing the light is accomplishing the object sought.

Diffusing the Light. — Whenever light is too concentrated for comfort, it must be broken up, distributed or diffused. This is the principle involved in good illumination, that no glaring centers reach the eye. The eye in this respect is not only considered, but the eye with respect to the general amount of light required for it. Diffusing light from a source at which it is concentrated seems to have the effect of increasing the amount of light, but this is impossible as the light is only made more effective. "By good diffusion we mean that the light rays radiated from the lamp should be so reflected and broken up that the apparent source of light is much enlarged. This does not allow a large amount of light to be concentrated in any one ray as it leaves the lamp, but instead increases the number of rays and decreases the quantity of light per ray, thus avoiding the possibility of deep shadows and at the same time reducing the glare. Light shadows upon the roadway are by no means objectionable, but a deep shadow places that portion of the street surface in almost the same condition that would result from no lamps at all along the street. In fact, a few deep shadows at close intervals will ofttimes make that part of the street more dangerous than if there were absolutely no lights, for with these few shadows travelers do not exercise the same degree of caution as on an unlighted street. As a matter of fact, however, greater caution should be taken than where there are no artificial illuminants, for then the sky provides a uniform light, though of a very low value." The deep shadows resulting from poorly diffused artificial light, have the same effect as a flickering light source upon the eye of the observer rapidly passing through alternate light and dark spots." Thus, it becomes evident that glare is the bugbear of lighting and the way to eliminate it is the way to eliminate its companion bugbear — shadows — by means of a good system of diffusion. But the instrumentality of diffusion should be no excuse for inefficiency. Many of the globes employed that reduce glare, also absorb light. What is the use of using the best brains to produce electrical efficiency throughout and then barbarously destroy this efficiency optically. Refracting rays are not destructive of them, but the rays must be cut down in intensity and correspondingly increased in quantity without refraction destroying the general amount of light originally produced for illumination. The diffusion must be scientific or not at all.

General Rules of Lighting. — The general rules of lighting have been formulated and published by a writer whose name cannot be now given as it is at present unknown to the author.

Rule I. A sufficient amount of light must be supplied and so distributed as to give a uniform illumination.

Rule II. Street lamps should have as low an intrinsic brilliancy as is compatible with economy, and be so located that any glare will not interfere with ordinary vision.

Rule III. With the usual height and spacing the greatest intensity of light should leave the lamp at an angle of about 20 degrees below the horizontal.

Rule IV. The light should be steady, for flickering obviously reduces the illuminating efficiency of the lamps.

Rule V. There should be good diffusion of the light rays so as to avoid deep shadows.

Rule VI. The lamp should be placed fairly high, thus giving more light at distant points and avoiding long, distorted shadows from objects on the roadway.

The placing of lamps sufficiently high up, so that the interweaving of their rays on the street and sidewalk give a higher average of candle-power per square foot, than by having them widely separated, is the scientific way to follow. The use of a reasonably high, but not too brilliant candle-power is the thing. It is not difficult to get it, but it is difficult to strike the right adjustment. Experience, however, will prove to be the best guide, although references from room lighting will not prove out of the way either.

In a room, about 6 square feet per candle-power is a fair allowance. This would mean, in a room having a floor 12 × 12, or 144 square feet, an allowance of 24 candle-power to light it. This light is ample to read by and to do ordinary work. In fact, a single tungsten 20 candle-power would prove sufficient under ordinary circumstances. This would give an average of over 7 square feet per candle-power. In streets, half this light is more than sufficient, with the exception of crowded places. A street 300 × 75 feet would mean 22,500 square feet in total. An allowance of 14 square feet per candle-power would mean 1,607 candle-power actually required in distributed form to do the same lighting as a room requires. This cannot be done with arcs very effectively. As our authority states, "To minimize glare, we must either prevent the light rays from entering the eye directly or choose an illuminant of a relatively low intrinsic brilliancy. The former remedy is not always practicable in street lighting as it requires an excessively high suspension of the unit. We must, therefore, adopt the latter method, and instead of the large candle-power units, with their particularly high intrinsic brilliancy, use relatively small units placed reasonably high, or at the side of the street."

In street lighting it will be often observed, plenty of light is used, but it is not made effective. Diffusion, using smaller units, and placing the lights neither too high nor too low accomplishes this. Having no flickering, plenty of low candle-power rays and many light centers will do the work well. If the lamps are too high up the rays will reach too far away. If the lamps are too low down the rays will strike near the post. A uniform spraying of the light is secured by the right proportions of "height to poles" and nearness of them to each other. The public satisfaction obtained will then be ocularly demonstrated.

CHAPTER XX

THE ILLUMINATION OF INTERIORS

Reflecting Surfaces. — Pigmented surfaces absorb light. Polished surfaces reflect light. Translucent and transparent bodies collect a toll when light passes through them. These facts are a guide in the choosing of materials for the lighting of a room. A room is essentially a cubical space whose walls, ceiling and floor affect the light rays. The floors, ceiling and walls may be pigmented or they may not. If they are, certain physical conditions result which call for consideration in the lighting of such surfaces. As a rule they are pigmented, and for that reason are destroyers of light. While light is supposed to be reflected when it falls upon a given surface, it is a well-known fact that it is absorbed by a black and thrown off from a white one. But the degree by which it is absorbed and thrown off depends upon several things. The angle at which the light rays fall is one; the character of the surface is two; and the color of the substance covering that surface is three. As art and science combine in their proper consideration, it will be best to examine each and all conditions involved in these so-called reflecting surfaces.

Forms of Practical Illumination. — Light either falls directly upon an object or is thrown upon it indirectly from another surface. This is the final analysis, but the two forms of lighting may also exist in conjunction, called mixed lighting. Daylight illumination of interiors is of this type. It is both direct and indirect. The light rays come in the window, fall on the walls, and are reflected back and forth. Direct daylight is not as direct as it seems. It has to pass through fifty miles of air mixed with vapor before it reaches us. The sky, so called, is simply an ocean of air made blue by the vapor mixed with it. We are at the bottom of this gigantic sea. It is enormously greater than either of our water oceans. All light must penetrate miles of air, dust and cloud before it reaches us. It is thus diffused. When it enters the window, except on the clearest, brightest days, it is greatly reduced in strength. But the eye has been developed by it in countless ages, and is accustomed to its variations. Daylight suits it the best. So the efforts made in artificial lighting are to duplicate daylight. The eye is then pleased and the senses satisfied. Direct illumination is derived from shades sending the light down. Indirect illumination is obtained by sending all the light deliberately on the ceiling. Mixed illumination results from a translucent basin globe, which throws light up on the ceiling, and lets it pass down as well as through the globe to the area beneath.

The Dulness or Brightness of Walls. — Walls are an enigma to many a good housewife. In kitchens they like to wash them. In parlors they admire them. Paint, paper, and moresco cover a great many of them. Others are tapestried or clothed in silken garments. With paint they are shiny. With paper they are generally dull. Moresco is a sort of tinted and elevated kalsomine. It comes in simple shades. Walls may therefore be made dull, bright or medium. Like roast beef, one chooses according to taste. The illuminating engineer cannot control this taste in others or himself. If dull walls are chosen instead of bright the problem varies. Dull walls absorb light, according to their color. Bright walls reflect it, almost regardless of color. But a bright surface creates an image, a reflection. This hits the eye hard. A brilliant source of light imaged in a mirror-like surface, destroys the effect. The eye is bound to suffer. Bright walls are not beneficial. The polished surface creates a great contrast. Contrast in lighting is a bad feature if carried to excess. Diffused and even light is the best. But individual taste respects neither logic nor law. Some like polished wood walls. Other painted walls. Others enjoy the sight of a dull finish. The lighting in each case must be appropriate. The table is generally well lit. One writer says: "The brightness of walls is an important element, affecting ocular comfort probably more seriously than the illumination of the table plane. Generalizing, it is probably the best rule to avoid extremes of wall decoration, whether they be light or dark. If the walls are of high reflecting power it is important to so direct most of the lighting that the amount permitted to fall upon the wall will not make them so excessively bright as to be trying to the eyes. The illuminating engineer cannot control wall decorations, but he can control the light produced within the room, and can so direct it as to secure the best effects."

Sylvanus Thompson's Views on Wall Paper. — If your gas or electric light bills are larger than you think they ought to be, perhaps a good share of the blame for their size can be laid to the color of the paper on the walls of your home or office. So suggests Prof. Sylvanus Thompson, a noted authority in the electrical field. He says that most of us are prodigally extravagant, both of daylight and of the artificial kind for which we pay real money, and that much of this waste is due to using on our walls colors which absorb an unduly large proportion of light. According to this authority, there must be a revolution in our taste in wall paper before we can look for anything like a sufficient return for the money we spend for lighting. All the rich dark tones — the deep crimson which is so popular for dining-rooms on account of the impression of warmth it gives, and the various shades of brown, so much used in libraries and "dens" — must be replaced by pure white and very light shades, which absorb a minimum of light. This good lighting of a room depends not only on the disposition of the lights, so as to produce an adequate illumination, and on the proper shielding of the lamps so as to avoid needless glare, but on the nature of the wall surface on which the light falls, this well-known authority adds:

"Even when the illumination that is received by the walls is ample, the room may be badly lit, if the walls absorb too much of that illumination instead of giving it back by diffuse reflections. Few people are aware how much light is thus wasted and thrown away. The deep scarlet and crimson wall papers now fashionable for dining-rooms waste from 70 to 75 per cent.; brown paper wastes about 85 to 88 per cent.; even an ordinary yellow or buff wall paper wastes 50 to 60 per cent. of the light for which in most cases a high price is paid. On the other hand, white cartridge paper absorbs and wastes only about 20 per cent. of the light, while a whitewashed wall absorbs from 30 to 40 per cent. In suggesting a remedy, Prof. Thompson strongly recommends that both for economy in artificial lighting and comfort in the daylight lighting of large rooms, the ceiling should be invariably white, and the walls, if not white, should at least be of the very palest tints." These reasons are scientific and practical, but are they of any interest to art? People will decorate rooms to suit their own tastes until the crack of doom. The only thing that can be done to mitigate the evil is to avoid the use of exceedingly dark shades by advice, suggestion, and command.

Absorption of Light by Globes. — A paper and demonstration was given by Preston S. Millar before the New England and New York sections of the Illuminating Engineering Society, called "Some Phases of the Illumination of Interiors." The author illustrated his points with a group of miniature rooms. In these he tested the various forms of lighting and globes presented. He speaks of the danger of glare to good lighting; also of reflectors and their design according to the laws of optics. Of globes, he makes the following statement: "In reflectors, as well as in globes, and other forms of glass lighting auxiliaries, the degree of optical density is important, affecting both the performance and the appearance of the glass. This is an important feature to be considered in selecting glassware. In the now rather common forms of display street lighting, which utilize clusters of tungsten lamps in globes, very displeasing effects are sometimes encountered, due, first to the non-uniformity of the globes; and second, to the insufficient density which makes the location of the lamp apparent, instead of rendering the whole surface of the globe equally bright, making it appear a ball of light. Much of the lighting glassware in use in residences a few years ago, and, it is to be feared, even to-day, consists of etched or frosted crystal glass, which serves chiefly to give the fixture a somewhat finished appearance. It neither directs sufficient light usefully to make it efficient, nor conceals the light source sufficiently to make it attractive or of value in protecting the eyes. A group of three globes was presented for inspection by Mr. Millar as follows: A globe of crystal glass, roughed inside; a light opal globe, and a denser opal globe. The last presented a better appearance without involving serious sacrifices otherwise. The light absorptions of these balls were, respectively:

Frosted ball	6 per cent.
Light opal ball	13 per cent.
Dense opal ball	22 per cent.

These globes, according to the experimenter, were tested for results in a group of three miniature rooms, each supplied with a table. The results of the test of relative light intensities throughout the table plane (the level of the table) averaged:

Frosted ball	100 per cent.
Light opal ball	106 per cent.
Dense opal ball	95 per cent.

The author furthermore states: "I recently went through the interesting experience of making a comparison of the standard types of reflectors which were upon the market ten years ago, and comparing them with types now available. In regard to efficiency, the improvement has been very marked. Absorptions of 10 to 20 per cent, now rule, where ten years ago, absorptions of 25 to 40 per cent. were typical for reflectors of substantially similar light distribution characteristics."

Effect of Ceilings on Light. — Ceilings are the cause of difficulty in lighting in many cases. Houses with very high ceilings are far worse off than those with lower ones. Cases where the ceiling is decorated in dark shades are great light absorbers. Only mansions or private art galleries are apt to contain lofty ceilings, as was the vogue in the past. The apartment house now reigns supreme in large cities like New York. Space is at a premium. Every cubic foot is valuable as a rent producer. The result is low ceilings. Rooms with low ceilings are easily lighted. When the color of the ceilings is light, the effect is marked. When the coloring is inclined to be dark a heavy reduction of light intensity results. Experiments in this direction made by Mr. Millar are quoted in his own language: "The rooms have been equipped with three ceilings; one is white, and has about as high a reflecting coefficient as is likely to be found in practise. Another is cream colored, and reflects a smaller proportion of the light. A third is dark cream, approaching a tan, and reflects still less of the light. This latter is about as dark as one might expect to find employed in an indirect lighting system, where any attention is paid to coefficiency. Indirect lighting is so largely dependent upon the reflecting qualities of the ceiling, that the statistics of the illumination intensities in these rooms are of interest. The horizontal illumination intensity on the table plane averages for the three ceilings:

White ceiling	100 per cent.
Light cream ceiling	87 per cent.
Dark cream ceiling	58 per cent.

showing a reduced efficiency of 42 per cent. due to the superior reflecting qualities of the darker ceiling."

Contrast and Uniformity in Lighting. — Some natures are fond of gloomy decorations, and lighting in spots. Others love garish and barbarous contrasts. In the mosques of the Far East, in spite of the semi-civilized ways of the people, these and their ornate adornments, a harmony of color prevails. The light enters these places of worship with fine effect. The decorations are generally dark, and there are no contrasts. In America the difference is noted. Gold, blue, red, brown, and dark green are frequently found in house interiors. To light up an interior so decorated, that the illumination is ineffective, means the use of unusually strong light at certain points. The effect produced is bad. Contrast results to a marked degree. Plenty of light may be employed, but the color scheme kills it. But certain natures like this sombre tone. It is of a religious cast, such as is found in large cathedrals. The result upon one's spirits is quietening. It is generally found in homes of very severe respectability. But where life and high spirits prevail, the needed colors are light and brightening. Vaudeville houses, concert halls, and theatres devoted to comedy use the lighter shades. The first impression on entering is stimulating. And the same is true of homes. The lighter the walls, the lighter the place seems. With a light tone prevailing, the number of light units can be diminished. The lighting is more uniform. The need for extra lights at special points is obviated. Contrast is avoided and the room is pleasing and cheerful at night. Experience has taught that white is the best to use for the best effects. Complaints are made at times by wealthy patrons of decorating and lighting establishments that the result was a disappointment. The color scheme is generally the cause, and the patrons themselves are responsible for it. One instance was that of a house in which $60,000 was to be spent on new decorations while the owners were in Europe. A Turkish room was one feature. The coloring of Moslem decorations is dark. The light centers used produced an effect of contrasts. Heavy illumination would have failed. The owner complained of the dimness of the Turkish room. Such decorations cannot be treated otherwise.

Direct and Indirect Lighting. — Dealing solely with the question of distribution, it may be noted that most reading would be likely to be done near the center of the room, and that therefore the direct lighting system should receive some of the advantage in rating which the high intensity beneath the unit would appear to give it, says Mr. Millar. The relative higher intensities in the corners of the room with the indirect, and to a lesser degree with the semi-indirect (mixed) lighting fixture, are not of much advantage from a practical standpoint. In this particular installation (three miniature rooms lit by direct, indirect and mixed lighting) with the same flux produced by the lamps in each type of lighting, the average horizontal intensities are, relatively:

Direct lighting	1.61 foot-candles
Semi-direct lighting (mixed)	1.33 foot-candles
Indirect lighting	.91 foot-candles

It is generally believed that with conditions suitable for each system of lighting, the direct lighting system will deliver about twice as much light upon the table plane as does the indirect lighting system, while each will illuminate the walls moderately. These facts, obtained by Mr. Millar, are very instructive in showing that if a reading place is desired with a strong light, direct lighting is the thing. But if the decorations are to be shown, the character of the wall paper, the general ensemble of the room exhibited, then mixed lighting will do it. This being a combination of direct and indirect can hardly fail to accomplish the end desired, namely, satisfactory illumination for the occupants. This would in all probability bring out the characteristics of the room sufficiently to show where the decorator left his best touches.

What Constitutes a Well-Lit Room. — By recapitulation, it is possible to come to some conclusions regarding a well-lit room. The things considered so far have been the following: Reflecting Surfaces; Forms of Practical Illumination; the Dulness or Brightness of Walls; Views on Wall Paper; Absorption of Light by Globes; Effect of Ceilings on Light; Contrast and Uniformity in Lighting, and Direct and Indirect Lighting. The next best thing to do is to state the features of a well-lit room. They are as follows:

1. A room whose character is preserved by the lighting being in harmony with its color and equipment.

2. A room in which all objects can be distinctly recognized, whether on walls, floor or ceiling.

3. A room in which the reading of a newspaper or a book can be done without risk to the eyes.

4. A room in which the light is not too lavish; a room not giving the impression of being over-lit.

5. A room devoid of striking contrasts in light; no brilliant spots making the rest seem dark.

6. A room from which any kind of glare is absent, by the choice of appropriate globes for the lamps.

There may be other items than this, but the majority are here given. They almost constitute commandments to the illuminating engineer. A well-lit room necessarily includes a room of correct dimensions. One of lofty ceiling, or lit by ceiling lights set in like stars, constitutes a variation from the general run. Such rooms and such lighting is unique. Also cases where cornice lighting is employed to shed down light rays, belong to the same category. Although an art in many respects, a well-lit room is governed, as far as that effect is concerned, by certain laws that are thoroughly scientific in character and application. Color, light, and position are the trinity to be remembered. The tone effect, the amount of light, and the placing of them, are fundamental. Choice of globes comes next. Then obtaining an unqualified acceptance with a mingling of emphatic approbation would seem to conclude the problem.

CHAPTER XXI

THE SCIENTIFIC LIGHTING OF A HOME

Introduction. — The proper lighting of a home must be done scientifically, if the purpose in view is to be accomplished. It is essential to have the lighting produce the impression of *comfort*. Comfort embraces the things producing what might be called brightness in a home, in contradistinction to what what is termed gloom. Furniture, carpets, rugs, wall-paper, paint, and ceiling tones, comprise the elements generally included as decorations. The prevailing shade, or varied colors of decorations, produce an *ensemble* which give a room character. Fundamentally, it may be said, the lighting of a home must preserve the character. While the lighting may stamp a room or rooms with individuality and the decorations be made to suit, as a rule it is the other way. The lighting is supposed to suit the decorations. In a simple home they consist of the wall-paper, the ceilings, and the floor. In a more elaborate home may be found silk, satin, or tapestry-covered walls; frescoed ceilings, possibly walls with mural decorations to be properly lit. The ceilings might be high, the rooms very large, and the floors polished. Many conditions exist which affect the result. Those loving sombreness will resist the use of much light. Others, fond of brightness, will welcome light in every corner. Color, taste, decorations, dimensions, purpose of rooms, and economy dictate the limitations of lighting, as regards both its quality and quantity. In the scientific lighting of a home, certain fundamental principles should be followed to overcome difficulties of this type.

Angle of Illumination. — All light-producing centers cast their rays in a specific manner. Some throw the light up, others down, and others sideways. The fact to be noted, however, is *the angle of the greatest illumination.* All kinds of lights possess this, but it must be discovered by actual test. In olden days the flickering rays of the pine torch were all that could be depended upon. At a more advanced age, the days succeeding the archaic period in early Egypt, and in Palestine and Greece, the oil crux was in use. The candle was invented and used in Europe and England at a later date. Then came whale oil and kerosene oil lamps, succeeded by gas and electricity. In each age the difficulties of lighting, with the particular class of rays in use, were met as well as possible. The fact remained, however, that in the candle period they could not place these illuminants too high up. And we are witnesses to-day that we cannot place incandescent lamps too low down. On the other hand, on account of the quality and intensity of the light, incandescent and arc lamps can be placed high up, at the ceiling, if need be;

while the older and weaker lights have been and are placed lower down to be effective. The intensity and angle of illumination determines this. As one writer states: "If the maximum candle-power should be nearer the horizontal, too much of the light would be wasted on the sides, . . . while if the maximum candle-power should be nearer the vertical, too great an intensity of light would be concentrated under the lamp. In order to secure the desired illumination . . . the maximum candle-power should be given off at an angle varying from 10 degrees to 30 degrees below the horizontal." The obvious intention shown here is to produce a uniform illumination. By altering the position of a given light center, with respect to the part producing the greatest number of rays, the light can be cast at a needed angle. But it would be best if the angle at which the light is most needed coincides with that which is native to the light center and which is most appropriately termed the angle of the greatest illumination. This is one of the first principles to observe in the scientific lighting of a home. If this cannot be accomplished, however, the use of reflectors is necessarily called into use, either to avoid glare or to direct the rays to a point where they will accomplish what is expected of them.

The Character and Purpose of Reflectors.— Reflectors are used either to diffuse or to redirect the light. If the light is intense reflectors and globes are absolutely necessary. Some globes act in both capacities, sometimes merely as reflectors. A reflector in the strict sense of the word is, as its name implies, a device for directing the rays in the direction required. A common example is a mirror or any other polished surface; but there are others not polished, having dull, white surfaces, which reflect and, to an extent, diffuse the light. Consequently, it is necessary to distinguish between the two kinds: those only reflecting, and those only diffusing. The first class would be genuinely termed reflectors. The second class would properly belong to the type of devices called globes. They are diffusers, and their purpose is to make the brilliant light center seem larger and more endurable to the eye. They are the means of avoiding glare, but the price paid for this is the absorption of a heavy percentage of light from the light-giving source.

The Principle of Diffusion. — Light is a form of radiant energy. All forms of energy can be intensified or reduced. As light is due to certain visible vibrations of the ether, it is evident that any concentration of a group of waves of very short lengths would produce intensity. On the other hand, it is equally evident that a group of such waves representing what is popularly termed an intense light, can be scattered or diffused by means of prisms. The basic idea in lens construction is to apply the principle of a prism to the production of different forms of light. A prism refracts light. It has the power of bending the rays. Considering a circle as being composed of a many-sided polygon, it is clear that a concave or convex lens consists of a great many prisms. The prisms refract the rays, either to concentrate them, as in the case of a convex lens, or to diffuse them as in the case of a concave lens. Consequently, when a given, intense light-center is to be relieved of its concentration, some optical device must be called into use, which will spread the rays in a practical manner. By means of such a device, where 1,000,000 rays are concentrated over a square inch area, by a proper diffusing apparatus the 1,000,000 rays can be uniformly scattered over 10 square feet of area. Each individual ray is not to be choked by this means, but preserved in its original strength as far as possible. Covering a greater surface reduces the intensity of the light per square inch or square foot, but the total effectiveness of the light is supposed to remain the same.

In diffusing light, however, two things are apt to occur: First, the individual rays are reduced in strength. Second, a percentage of the rays are lost entirely. Rays are reduced in strength by passing them through media that destroy them in part, such as globes of different colors and grades. Many light rays are lost by not being directed to the area to be illuminated. This last may be due to the fact that they cannot be secured for that purpose.

Glare. — Electric lighting is becoming more and more a form of illumination from intense light-centers. The arc is naturally the strongest of artificial lights. Since its invention the incandescent lamp has gradually increased in light intensity. The light has become whiter, and the number of rays per unit area of filament surface risen enormously. The result has been the introduction of glare in homes where electric lights are used. Many complain that electric lights are too glaring. This is the result of unscientific and careless handling of the light after its installation. Glare is either due to contrast, or to the undiffused state of the light. Contrast may be, and generally is, the result of brightly illuminated spots in a room, and heavy darkness in other places. On the other hand, the globes employed, or the opaque or partially opaque shades or reflectors in use may fail to suit the needs of the case. Too transparent globes will produce glare. Reflectors badly placed will produce glare. Glare will also result from lights so placed that even though shades are used the rays fall upon the sensitive and unprotected eye in all their painful intensity. Consequently, four things may be considered as the obvious causes of glare: First, poor diffusion of the original light. Second, the lights are exposed, in part or whole, even though shades or globes are employed. Third, the contrast in different parts of the room produces glare, because of the non-uniformity of the light distribution. Fourth, glare is not due to excessive light, but the angle of the rays with reference to the eye.

The Psychology and Hygiene of Lighting.— There is sufficient relationship between the nervous system and the body to arrive at certain conclusions regarding the use of electric lights in homes. It is well known that for thousands of years the ancestors of this race had, at the best, flickering candle light or hearth light to depend upon at night. As the result of this those desirous of improving themselves after nightfall had recourse only to a very imperfect form of light. Bad eyesight in some and perhaps many families resulted congenitally. The widespread use of eye-glasses to-day is proof of the defects of the former lighting system. But some of this defective vision, it is claimed by oculists, is due to the forms of light in vogue to-day. Eye-strain results from it, and a host of other evils. It has been calculated by some efficiency experts of large factories, that in a thousand men, 300 will wear or need glasses. This defectiveness is not the result of poorly lit factories, but of badly lit homes. These experts further assert the amount of light in many homes is quite sufficient, but it is badly placed. Poor eyesight results from this, and in a factory of 1,000 men, the loss of time of 10 minutes a day by 300 men results in a total loss of 3,000 minutes altogether, or 50 hours. At the price of 25 cents an hour, the factory loses $12.50 a day or $75.00 a week. The total annual loss is about $4,000, which, figured at compound interest for the life of a business (a matter of 25 years), would aggregate about $150,000 in conservative figures. These figures are presented to show the selfish reason why large employers of labor ought to be interested in the homes of their employees. Why science is necessary to select the correct coloring of walls and ceilings. Why it pays best to have the best light, placed in the best manner. Why it pays the worker to avoid eyestrain, which induces headaches and other associated troubles. And finally, why the new generation, the children of workers, or of those of the best circumstances, ought to be brought up with sound sight, free from the need of eye-crutches in the shape of spectacles.

The Effect of Wallpaper upon Light Bills. — Much light can be used in a room that will remain sombre. This is the direct result of decorations. The wallpaper and ceiling are the most obvious to consider. The fact that certain kinds of wallpaper and colors absorb light is no new proposition in physics. When electric lights are employed for effective illumination, it is necessary to consider the surfaces upon which they act, before drawing conclusions as to the advantages derived. Sylvanus Thompson, the noted author of "Dynamo Electric Machinery," a well-known name in electric lighting, expresses his opinions freely on the subject of interior lighting and decorations as follows: "If your gas or electric light bills are larger than you think they ought to be, perhaps a good share of the blame for their size can be laid to the color of the paper on the walls. Most of us are prodigally extravagant, both of daylight and the artificial kind, for which we pay, and much of this waste is due to using on our walls colors which absorb an unduly large proportion of light."

According to Professor Thompson, "there must be a revolution in our tastes in wallpaper before we can look for anything like a sufficient return for the money we spend for lighting. All the rich dark tones — the deep crimson which is so popular for dining-rooms on account of the impression of warmth it gives, and the various shades of brown, so much used in libraries and 'dens,' must be replaced by pure white and very light shades, which absorb a minimum of light. Thus, good lighting of a room depends not only on the disposition of the lights so as to produce an adequate illumination, and on the proper shielding of the lamps so as to avoid needless glare, but on the nature of the wall surface on which the light falls. Even when the illumination that is received by the walls is ample, the room may be badly lit, if the walls absorb too much of that illumination instead of giving it back by diffuse reflection. Few people are aware how much light is thus wasted and thrown away." The following data are of use to those preparing to repaper their walls with designs and colors they think will look well. The figures giving the degree of light absorption will probably modify their tastes somewhat if the saving of money is of any importance to them.

1. Deep scarlet and crimson wallpapers, now

fashionable for dining-rooms, absorb from 70 to 75 per cent. of the light striking it.

2. Brown paper of the darker shades, employed for dining and smoking rooms largely, absorbs from 85 to 88 per cent. of the light striking it.

3. An ordinary yellow or buff wallpaper of a comparatively lighter shade than that above, absorbs from 50 to 60 per cent. of the light striking it.

4. White cartridge paper, of the kind frequently rejected as lacking in ornamentation, absorbs from 20 to 25 per cent. of the light striking it.

5. A plain whitewashed wall or one coated with light shades of so-called "moresco," absorbs from 30 to 40 per cent. of the light striking it.

The remedy suggested as a means of preventing this loss is to have the ceilings white and the walls at least of the very palest tints.

Shades and Globes for Rooms. — A certain amount of scientific consideration is given to the choosing of shades and globes in a room. If a home spends from $2.00 to $8.00 a month for light, from $25.00 to $100.00 a year, it is a senseless economy to save in other directions and be wasteful in this. Poorly chosen wallpaper and badly selected globes and shades can have the effect of making the light very costly or the decorations referred to, in the end, excessively expensive. For instance, 8 globes costing $2.00 apiece or $16.00 in total, which waste from 25 to 50 per cent. of $100.00 spent for electricity, would cost, the first year, 16+ 25 or 16+ 50 dollars, either $41.00 or

$56.00. This would be due to the light wasted through their character and color. The data to be guided by are given as follows with respect to plain, opal, or colored shades and globes:

Character of Glass	*Per cent. of Wasted Light*
Ordinary pane glass	About 10
Cut or pressed glass	From 15 to 25
Ground glass	From 25 to 40
Opalescent glass	From 25 to 50
Red glass	From 30 to 60
Blue glass	From 15 to 30

If the clear globes do not possess powers of diffusion, the glare resulting from their use and the deep shadows cast will make the lighting very disagreeable. In choosing globes the following points of view must be taken: First, cost of globe; second, the degree of diffusion of the light; third, the degree of absorption; fourth, the art in their design, and fifth, the fragility of the shade or globe.

The Satire of Non-Economy. — In the electric light plant proper, every nerve is strained, so to speak, to secure the best possible returns from the coal, boiler, engine, dynamo, and lamps. When a few per cent. is gained by skill in arrangement or the improvement of a part, it seems a great advance. Everything is therefore guided in the direction of the highest efficiency, from the coal heap to the light emanating from the most improved lamp science and skill can produce. After getting all the light possible into a room by these carefully developed improvements, it seems a satire on our intelligence to allow it to be absorbed by the walls and prodigally wasted by the shades and globes. In the scientific lighting of a home, every rational means of aiding in the general efficiency would seem to be the natural thing. If the prevailing taste in wallpapers and shades and globes is inimical to this policy, the designers and exploiters of these devices ought to be re-educated, so that their plans will be in harmony with those that tend to a higher economy in lighting.

The Aims of Modern Illumination. — The aims of modern illumination could be called threefold: First, the quantity; second, the quality; third, the cheapness of the light. All three goals have been reached individually by different inventors. The triple combination in one lamp, however, is the correct objective point. The flaming arc and mercury-vapor lamp give quantity. The latest advance in tungsten filament lamps give quality, as well as the so-called vacuum or gas-filled tubes of the McFarlan-Moore system. For cheapness in light alone, the flaming arc is the leader, but the cost of carbons, the labor of cleaning and renewals, and the inconvenience of that process affect this point of view. Consequently, lamps producing quantities of light may not do for residential interiors. And lamps producing quality of light may be considered by some too elaborate or expensive, such as the vacuum tube system. The monthly bill to be paid is the final test with the great mass of home-going people. Fortunately, there is every indication that the tungsten filament or some metallic filament lamp is going to reach an unexpected efficiency in service. A one-watt-per-candle-power lamp of the tungsten type would represent quantity, quality, and cheapness. At the nominal cost of 10 cents per kilowatt-hour, a one-watt-lamp would produce 1,000 candle-hours. As 10 cents, with the carbon filament lamp, used to be paid for from 250 to 333 candle hours, it is easy to see where the advantage may be found. Getting from three to four times as much light of superior quality for the same money is an enormous advance. This being the case, it would seem as though the aims of modern illumination with small units for interior lighting have been attained with a remarkable degree of success to date. Advances beyond this point will extend to a field in which it is evident a revolutionary change would be expected. This would mean universal electric lighting, without prohibitive cost.

CHAPTER XXII

ACCIDENTS DUE TO BAD LIGHTING

Goethe's Plea. — Goethe's famous plea for "Light, More Light," is finding, nowadays, a number of strenuous seconders. They do not, however, want the spiritual, mysterious form of light which, presumably, the German poet called for on his deathbed, but the more prosaic form supplied by the sun and — after the sun's business hours — by incandescent globes, gas fixtures, and all the other paraphernalia of artificial illumination. Their cry of "light, more light" is not voiced poetically at all; they want the additional supply for unpoetic but extremely useful places — factories, hospitals, schoolrooms, shops, etc. They contend that we are blinding thousands of people and impairing the eyesight of tens of thousands more by allowing them to work in places where the light is bad.

The New Crusade. — One of the most earnest among the leaders of the new crusade is Mr. Leon Gaster, founder and secretary of the Illuminating Engineering Society of England, and editor of its official organ, *The Illuminating Engineer*. He is now in this country endeavoring to stir up sentiment among the Americans for the better lighting of their places of business, in order to safeguard not only the eyesight of workers from strain and destruction, but their limbs from injuries due to inadequate illumination. And lest anybody think that this sort of accident is uncommon, it is well to point out right here that, in a recent report, a New York casualty company placed inadequate lighting first among the causes of injury to employees in factories.

Last week Mr. Gaster, in a lecture before the New York Section of the Illuminating Engineering Society explained the great progress that has been made, toward better lighting in France, England, and other European countries, and urged his American hearers to help him in his efforts to make the United States fall into line. He amplified what he had said at this lecture in a talk with a New York *Times* reporter, which he found time to give between various appointments which he had in New York, Philadelphia, and elsewhere, for Mr. Gaster, is an extremely busy and enthusiastic worker and allows not a minute to lie idle on his hands.

"And mind you, I want you to understand one thing right away," said Mr. Gaster, at the beginning of his remarks, "and that is that I'm not trying to teach Americans the advantages of up-to-date illumination. Not at all. It was here in the United States that the whole movement started. It was here that the term 'illuminating engineer' originated, that the first illuminating engineers set up in business. Oh, you can't teach your grandmother to suck eggs! I know that as well as anybody.

Selling Light. — "But over here in your country the movement has become too commercial. Many Americans have looked upon light merely as a commodity to sell. You have gone ahead, putting it up in the best form for selling, without sufficient regard to the other very important phases of the matter. As a result of this, you have allowed several other countries, notably France, and including England, to forge ahead of you.

"Now that isn't right. The country where illuminating engineering originated should be in the lead in all that concerns illumination. It is with the hope of making Americans realize this and get into first place that I came over here five years ago, and am back here again now.

The Minimum Light. — "Lighting in factories, schoolrooms, shops, and other places must be improved. Here we are, giving all sorts of attention to heating and ventilation, yet, almost everywhere, light is neglected — that is, in so far as its effect on the eyes is concerned.

"In lighting, three things must be considered — the quantity of light, the placing of lights so that there shall be no glare, and the proper provision of shadow. If any one of these things is neglected, improper lighting and injury to workers is bound to ensue.

"The first necessity in lighting, whether natural or artificial, is that there should be sufficient light for the work to be done. In Holland they have fixed a minimum of illumination for general work, and in certain trades, recognized as especially trying to the eyes — such as jewelry, sewing, knitting, embroidery, engraving, etc. — a special minimum has been strongly impressed by the necessity for definite rules specifying the amount of light required for various purposes, and has given instructions that photometric measurements be carried out in a large number of factories. The agitation for better lighting has already been carried up to the House of Commons, and a committee is going to be appointed to investigate the matter.

"As far back as 1908 the need for some standard of illumination was making itself felt. My object in coming to America is to try to have such a standard fixed here. I don't expect to see the same standard fixed for every country. That would be impossible. Conditions vary altogether too much.

"It must not be assumed that the provision of sufficient light is all that is needed. It is equally important that the light should be wisely used. One of the greatest defects in much of the factory lighting of to-day is that the lamps are not sufficiently shaded and are too frequently placed in positions in which they dazzle the eyes and impose a distinct strain on vision. Very few of the modern illuminants are sufficiently mild in intensity to allow of their being used at close range in this way.

Screening the Light. — "When the eye is constantly encountering these bright lights the strain of doing work is naturally increased. The lamps should be screened by some form of well-designed reflector which, besides removing the glare, directs the light downward on the work where it is actually needed. To have the light on the object, not in the eyes — that is the idea.

"Another matter requiring attention is the placing of the lamps. When you write, for example, it is a continual source of inconvenience if the lamp is situated on the right hand so that a shadow of the hand is cast at the point where you wish to see the page. This defect is not an uncommon one in banks and offices. In all mechanical operations, like cutting, drilling, etc., it is self-evident that the direction from which the light falls on the work is very important. Arrangements of lights which cause a shadow of the head or body of the operator to fall across the object on which he is working should never be tolerated. Yet they are common in the lighting systems of a great many factories here and in European countries.

"Often lamps are placed in a workshop without reference to where the light is needed. Sometimes the positions of the furniture have been entirely altered since the lights were originally put in, with the result that most of the light falls on the floor, where it is useless, instead of on the tables, where the work is being done. If there were inspectors, whose duty it was to watch for just such conditions, they could be easily eliminated.

"There is something else which is quite as important as safeguarding the eyesight of working people — protecting them from injury, from loss of life, even, by improving lighting conditions. Those who have gone into this subject at all know how very common accidents due to bad lighting are.

Bad Lighting. — "Bad lighting, you know, headed the list of causes leading to accidents in a recent report of one of your New York casualty companies. It was shown that, during the months when darkness set in early, and artificial lighting had to be depended upon to a greater extent, the percentage of accidents rose steadily until, in the darkest months, it assumed extraordinary proportions, and, throughout the year a relatively large proportion of accidents occur after 4 P.M., which is the time when artificial light begins to be necessary. Sufficient investigation of accidents caused, possibly, by poor lighting, has not been made as yet, but it is more than likely that, if it were, many unexplained mishaps would be found to be due to badly placed or insufficient light.

"Dangerous machinery should be well lighted. It is useless to place a guard around a dangerous machine if the light is so poor that its outlines cannot be clearly distinguished. Many a machine that would be safe in a well-lighted room becomes dangerous to life and limb if run in semi-darkness.

"Investigations in England have produced some startling results. One investigator, in his report, pointed out the constant danger arising from insufficient lighting in passages, which often led men to stumble over light obstacles in their way. In the case, say, of a man carrying molten metal, a slip of this kind might be no small matter. When the man's eyes have been dazzled by the brilliant light from molten metal, he is naturally likely to stumble when he finds himself suddenly in a dark or badly lighted corridor.

"The same report also told of the frequency of accidents among men working overtime in ship-building yards, due to the feeble light with which they were surrounded.

"But sometimes attempts to remedy such conditions are as bad as the conditions themselves — or worse. A bright light placed at the top of a flight of stairs, or in front of some obstacle, in such a way that its rays go straight into the eyes of any one who may approach instead of fall in on the obstacle, may actually be the cause of a stumble or of a serious fall. I heard recently of a case where a man walked off a platform and was killed, simply because his eyes were dazzled by a light set to prevent just such an accident. Even the men working close beside him did not realize that he was not on solid footing until he toppled off into space.

Dazzling Light. — "Not only should dazzling light not be installed, but care should be taken that lights should shine in the right direction. For instance, in certain tailoring establishments, where workers hold their hands close to the sharp cutting edge of tools, a shadow obscuring the tool for a moment may lead not only to the spoiling of the work, but also to the mutilating of the worker's hand. And there is a commercial aspect to this: A badly lighted plant of this kind is apt to be neglected and allowed to become dirty, until, eventually, its usefulness is impaired and the way is paved for its complete breakdown.

"Speaking of accidents to workmen, there would be a great decrease in their total number if employers could be induced through the action of insurance companies, to have their plants properly lighted. For instance, suppose a casualty insurance company insuring against accidents found that a certain plant had poor lighting arrangements and that persons working there were likely to receive injuries on account of this defect. Suppose that the insurance companies promptly raised the rate of insurance on such a plant to a figure above that charged on the plants which were properly lighted.

"That would put the thing on a practical basis at once. Employers who were assessed the higher insurance rate would doubtless see, without delay, the expediency of introducing a proper lighting equipment in order to obtain the low insurance rate.

"And there is a good commercial argument on the other phase of the question — the damage caused to the eyesight of workers by bad lighting.

"'At my factory the work is piecework,' employers have told me again and again. 'What do I care if a worker turns out fewer pieces because he hasn't enough light? I have to pay him only for the number of pieces finished, don't I? So, what difference does it make? He is the one that suffers, not I, by insufficient lighting.'

"Against such an argument, I invariably answer:

"'You are wrong. The principal sufferer is yourself. On account of the imperfect lighting the worker turns out not only fewer pieces, but pieces of an inferior grade of workmanship. After a while this inferiority in the output of your factory is sure to make itself noticeable. I know of many cases in England where factories have been nearly stricken off the list of purchasers of their goods on account of the constant deterioration of the goods manufactured and I feel sure that this deterioration has been due largely to the poor lighting in the workrooms where those goods were turned out.' By such arguments, I have succeeded in convincing a number of employers, and caused them to improve the lighting of their workshops.

School Lighting. — "Nor must we forget the lighting of schools. That is quite as important as the factory question. Since education is compulsory, parents who are compelled to send their children to school have a right to demand that their children be enabled to work in a proper light. In a recent investigation conducted by the London County Council, it was found that a large number of school children were suffering from incipient curvature of the spine and other troubles on account of having to twist themselves into unnatural attitudes at school in order to get the light to fall in such a way that it did not hurt their eyes. Another common fault in school rooms is the arrangement of lights in such a way that, when a teacher is explaining something written on the blackboard, the rays strike straight into the eyes of the pupils instead of falling on the blackboard.

"This same sort of fault is common in homes also — lights are placed in such a way that they blind the eyes of those who are reading books, instead of illuminating the pages that are being read. Likewise, kitchen lights cast a shadow over cooking utensils on a stove and shine straight into the cook's eyes, instead of shining on the stove, and thus making cooking easy.

"But you must not believe, from all this, that nothing is being done to remedy the situation. France is the leader in this respect. The French Government has appointed a Committee on the Hygienic Aspects of Illumination, composed of prominent physiologists, oculists, engineers, physicists, and inspectors of factories. The main objects of the committee are:

"To study, from the standpoint of general health, and its effects on vision, the various methods of artificial lighting now used.

"To determine the composition and quality, from a hygienic standpoint, of the different combustible illuminants, and to examine the effects of prejudicial gases and the amount of heat developed thereby.

"To fix a certain minimum amount of artificial illumination to the normal requirements of vision.

"To study the most practical methods of measuring illumination.

"To formulate recommendations governing the best means of applying customary methods of lighting to the chief varieties of industrial operations.

"To present to the Ministry a report on the subject of short sight and the impairment of vision, and on the best methods of guarding against the cause of myopia.

"I think that this excellent step on the part of the French Government should be followed by other countries, especially by America, the pioneer in illuminating engineering. I trust that the time is not far distant when similar committees will have been instituted here and elsewhere, and when all will be communicating the results they have obtained to each other, for mutual benefit. In such a matter international co-operation would be of immense assistance. Thorough investigations conducted in different countries would be immensely valuable to another country in determining the best methods for improving the lighting stituation at home.

"For instance, we have made such a thorough investigation in England in readiness for bringing the lighting situation again to the attention of Parliament, the chief inspector's report of factories for this year has a special section containing thirty-eight pages devoted to illumination of factories in which was published most exhaustive data from no less than one hundred factories, so that when we agitate for more reform, we shall not be compelled to devote ourselves to idealistic generalizations. Instead, we shall go to the front, armed with the most convincing sort of data, collected by a first-class expert. We shall be able to show how many men have lost their sight with imperfectly lighted workrooms, how many have had their sight impaired, how many have been killed, how many maimed — everything.

Legislation. — "That is the right way. I am emphatically against all sorts of hasty legislation, but a departmental committee should be appointed composed of experts, who should report after exhaustive investigations the merits of the case. Then the Government authorities will be in a position to act promptly and well, and the probability is that something of lasting good will be brought about.

"'Why do you come to me?' a certain high Government official in England said to me when I presented a lot of statistics regarding bad lighting to him.

"'Because you are the right man in this case,' I replied. 'It was you, wasn't it, who took up the anti-spitting crusade, who saw to it that a law was passed fining everybody who spits in cars and other places where consumption and other diseases spread easily? The advocates of the law against spitting presented to you such a formidable array of figures proving their point that there was nothing for it but to act.

"'It is the same way in this case. When you have gone over the figures regarding imperfect lighting — when you have realized the enormous amount of harm that is caused by it — then you will act, as you acted in curbing the practise of promiscuous spitting.'

"Light is good for the body as well as the soul. Let us provide it of the best kind and in the best way."

CHAPTER XXIII

RATES FOR ELECTRIC COOKING

General Aspect of the Problem. — If one system of cooking has advantages over another there is every reason to expect its final acceptance by the public. To establish this fact, however, it is necessary to prove to the lay mind that the system is more than a novelty. Of all types of conservatism, there is none greater than that exhibited by the domestic circle and its head, particularly as regards methods employed to perform certain household duties. When it is realized that the general duties to be discharged each day in the house have been preserved in all their unvarying monotony for many centuries, perhaps thousands of years, and do not differ essentially in any race, it is not difficult to realize that customs have become very deeply rooted. in some cases to such a degree as to be unchangeable. The problem, therefore, of substituting for the old methods those that are entirely new is one fraught with difficulties. These difficulties may be analyzed, classified and discussed with some interest and profit. *First,* it may be stated that the greatest of them all will be to persuade housekeepers to adopt an entirely new way of doing things. *Second,* it must be shown that the new way is not one that will involve any unreasonable expense as regards equipment required. *Third*, it will be necessary to guarantee that the new way and new equipment will not be more expensive to operate than that discarded.

The New Way and Its Cost. — Although those familiar with the latest inventions and applications of electricity are not amazed at the notification of new wonders arriving, having expected such things in the natural course of events, the general public is only stirred up through the daily press and magazine articles. Consequently, unless an invention be of general and vital interest, such news does not arrive very quickly. As a result many minor inventions only become known through forms of solicitation, circularizing or advertising. What might be called the new way of doing things and the cost of this way are still comparatively unknown. The public knows a little about lighting and its charges, but regarding cooking, the use of electric heat for household purposes, its ideas are still very vague. Without intending to discuss the new way, except with reference to the subject under consideration, there is one point at least that should be emphatically stated: it is, that the new way is strictly scientific, and, therefore, possesses a great advantage over all others. But advantages are not always the strongest arguments to use when they finally become reduced to one, more stubborn than the rest, which proves that competition cannot be met, unless the cost of the power consumed for an ordinary service is one that will not neutralize the said advantages.

This is an age of economics, and no system can thrive which does not provide within itself an effective way of meeting competition. The fact that many agreeable features are associated with a new way of cooking, will not convince the average housekeeper that they supply a reason for a heavier cost. It must be realized that the service rendered to-day by gas will provide cheap and good cooking. One of the inexorable demands of the prevailing law of competition is that something as good if not better must be supplied at the same cost or for less. The scientific feature associated with electric cooking is its exactitude. Cooking may be an art, but this refers more to effects upon the palate than those produced in the oven. Electric heat provides a fixed temperature for each particular type of cooking and thus illustrates the main feature of the new system. It is exact, and therefore the products of it are more reliable than by other means. This is what is meant by its being more scientific. Yet, unless the rates charged permit of competition as to monthly charges the average housewife will remain skeptical.

The Scientific Cost of Electric Heat. — The central stations are face to face with a problem worthy of their steel. The fact that they extract heat from coal and then transform it into electricity is the first chapter of their experiences. From this they obtain energy for light and power, both of which are widely admitted economic successes. But to take this energy, this possible 14 per cent. of the original heat of the coal, and transform it again into heat, and with it compete with the full total of heat produced by coal or gas is almost a paradox. The only hope they find is in the extreme wastefulness, the lack of economy of other heat systems, and the extraordinarily high economy of the electric system. The chimneys of the United States are absolutely wasting over 2 pounds of coal for the benefit of every one that is obtained. This enormous waste is the result of the prevailing system. It is true in all fuel-burning plants extracting and using heat. The highest products of the resourcefulness of man, in this respect, even to-day, mean that the great bulk of the heat of the coal is wasted. For instance, 1 pound of good coal contains 14,000 British Thermal Units. A kilowatt-hour can produce 3,412 British Thermal Units. According to these figures 1 pound of coal contains as much heat energy as 4 kilowatt-hours. Were it not that the present method of extracting heat from that pound of coal is very faulty, there would be little or no chance in an economic sense of competing with gas or coal heating in homes, even for cooking. The calculation relating to this conclusion is as follows: The joule is a unit of work which can produce heat equal to .7373 of a foot pound per second. It is the heat developed by 1 watt. In 1 minute a joule or watt produces $60 \times .7373$ ft. lbs. = 44.24. A kilowatt equaling 1,000 watts, therefore, produces $1,000 \times 44.24$ ft. lbs. per minute which = 44,240. A kilowatt-hour, therefore = $60 \times 44,240$ = 2,654,400 ft. lbs. But as there are 778 ft. lbs. to a British Thermal Unit, 2,654,400 ÷ 778 = 3,412 B. T. U. per kilowatt hour. Comparing 3,412 with 14,000, the number in a pound of coal completely oxidized, gives a ratio of about 13,648 B. T. U.'s for 4 kilowatt-hours, as compared with 14,000. It is evident that the pound of coal contains 352 more.

One can judge of the problem from these figures and realize their importance. One central station manager says hopefully, after considering the potential and actually obtained energy of a pound of coal: "In spite of this fact, however, certain general heating problems are so ideally adapted to the use of electricity as a medium as to render them immune practically from the cost standpoint on account of their greater convenience, cleanliness and adaptability." In the commercial sale and the exploitation of electric heat devices, the best reliance can be best placed upon competition of cost for cost. Gas and coal heating are in general favor in the average home. They are there because of the "new way" and its expenses whatever they may be. The apparatus and the installation expense are appropriate and expressive terms. The problem, therefore, is the way to success. As there are two kinds of electric cooking to be considered, what might be called domestic or that called commercial, there are naturally two considerations involved with respect to the idea of cost.

What to Charge to Meet Competition. — The loss of heat in transformation from the coal-pile to the electric heater, makes it necessary to meet competition in devices which produce their heat directly. Gas is not a direct heat because the coal is volatilized to obtain the gas, but the coke as a by-product pays certain of the expenses of the process. Irrespective of the conditions, however, the cost of gas-cooking is well known. Cooking by electricity can only compete fairly with it at a certain figure. That figure is a point of speculation with some, but is definite enough in practise. In Idaho, the Public Utilities Commission prepared a set of rates which laid special stress upon what should be charged for "Domestic Cooking." It made the following statement: "The domestic cooking schedule applies only when the connected heating load in cooking appliances equals or exceeds 2,000 watts, and when such is the case, small heating and single phase motor appliances, irons, fans, etc., may be used on the same circuit at these rates, but cannot be considered as a part of the connected heating load. (Rate) 3 cents per kilowatt-hour for the first 50 kilowatt-hours of current consumed per month; 2.5 cents per kilowatt-hour for all over 50 kilowatt-hours of current consumed per month." Some years ago, MacAllaster Moore, of the Simplex Electric Heating Co., in an article in one of our contemporaries made the following statement: "To do the entire cooking for a family on a competitive cost basis with gas or coal is a little different matter. All the above prices (those of the cooking of certain articles of food) have been figured at about the average lighting rate of 10 cents per kilowatt-hour, but an electric kitchen range demands, and in many cases receives, a better rate. In this respect some of our smaller communities can do better than the larger cities. A rate of 4 or even 3 cents per kilowatt-hour is not uncommon for such service, and it has been demonstrated by numerous experiments that at 2.5 to 3 cents per kilowatt-hour, electricity meets dollar gas on an even basis. From that point up to 5 and 6 cents the saving of time, the cleanliness and convenience, and safety of the electric range will frequently outweigh the difference in monthly expense. Current consumption varies greatly with the scale of living, but will average between 1 and 1.5 kilowatt-hour per person per day. At the higher value a family of four will use 180 kilowatt-hours per month, or $4.80 at the 3 cent rate, $7.20 at the 4 cent rate, $9.00 at the 5 cent rate, when doing all the cooking electrically." So here are the charges that will arise at rates prevailing as commercial. In many localities where greater gas meters are used, the total monthly bill for gas for cooking and light does not exceed $3.00 for a family of four. Wherever the housewife counts her pennies, as the majority do, it will have to be proven that not only is the service superior, but the charges equal or less.

Cost of Heating Water by Electricity. — The basis of calculations of domestic interest is that of heating water. If it can be shown that the possibilities of heating this cheaply are sufficient to invite its use the economic argument will favor the system. But the question is this: if it is proven that electricity is a competitor to gas that will lead to its acceptance as a source of power for heating, what are the costs in the station that encourage or discourage its use at a low price? The following figures are interesting, instructive and pertinent to the point under consideration based upon the estimate of only 12,000 B. T. U. per pound of coal. Starting with the heat of coal, which may fairly be said to have at least 12,000 B. T. U. per pound to be extracted, the heat efficiencies of conversion are as follows:

GAS.

1 lb. coal produces 5 cubic feet of gas.

5 cu. ft. of gas contain 3,000 B. T. U.

$$\text{Efficiency of heat conversion} = \frac{3,000}{12,000} = 25 \text{ per cent.}$$

In other words, the loss of heat units in the process is at least 25 per cent., in favor of which can be added the by-products of distillation: coke, coal-tar, etc. But the actual efficiency of conversion would not be materially altered by this fact. For electricity:

ELECTRICITY.

1 lb. coal produces 0.25 kw.

0.25 kw. contains 853 B. T. U.

$$\text{Efficiency of conversion} = \frac{853}{12,000} = 7.0 \text{ per cent}$$

The basis of only 12,000 heat units per pound of coal makes the efficiency lower than it would otherwise be. Some engineers claim a higher output in heat units than this figure. The allowance of 4 pounds of coal per kilowatt-hour means ⅓ of a horse-power per pound, or only 3 pounds per horse-power. With a type of engine and boiler now advertised, whose salient point is the use of superheated steam, the figures become more significant. In Germany an engine of this type is advertised as producing a horse-power-hour by the combustion of 1.5 to 2 pounds of coal. Consequently, it is possible that modern progress is such to-day that the 7 per cent. could be doubled without any great risk of refutation. Until higher efficiency steam plants are employed, however, these figures will have to be accepted. The rates generally charged for gas and electricity at present are:

GAS.

$1.00 per 1,000 cubic feet.
1 B. T. U. = .000167 cent.

As 5 cubic feet are equal to 3,000 B. T. U., 1 cubic foot would contain 600 B. T. U. This means that for .001 of one dollar, 600 B. T. U. are sold. On this basis 1 B. T. U. would cost 1/600 of 1 mill, or 1/600 of .001 of a dollar, which equals .000167 cent. For electricity:

ELECTRICITY.

$0.10 per kilowatt-hour.
1 B. T. U. = 0.00293 cent.

The ratio of costs between the gas and the electric system of producing heat is:

$$\frac{\text{Electric B. T. U. } 0.00293}{\text{Gas B. T. U. } 0.000167} = 17.5$$

The greater efficiency of electric heating means that the waste of heat by gas is greater. The differences are such that the figure 17.5 falls to about 4.4. In other words, to be able to sell electricity for cooking, heating, etc., to compete fairly with gas, electricity must be sold at 2.5 cents per kilowatt-hour. Then it is equal to dollar gas. If gas is sold for less or electricity for less the differences in cost will vary in proportion, according to the percentages of reduction.

In an article prepared some years ago by Max Loewenthal and published in the *Electrical Record*, the following facts were presented relative to the heating of water by electricity. "As an example let us raise the temperature of one gallon of water, put into an electric kettle, equipped with a heating unit and requiring about 700 watts, from 41° F. (5° C.) to the boiling point 212° F. (100° C.) without actually boiling. Consequently, 3,786 cubic centimeters (equal to 1 gallon) would be elevated 95° C., or $3{,}786 \times 95 = 359{,}575$ water-gramme-degrees centigrade or colories of heat be produced. But one calorie requires an expenditure of 4.18 joules, so that the work required to be done in raising a gallon of water to the temperature of boiling would be $359{,}575 \times 4.18 = 1{,}503{,}000$ joules.

At a cost of 5 cents per kilowatt-hour (equal to 3,600,000 joules) this operation would cost 2.1 cents; at 10 cents, 4.2 cents; and at 15 cents, 6.3 cents. In view of losses, however, such as the initial heating of the walls of the kettle, the radiation loss, and that due to inefficiency of heat transmission from unit to kettle, the efficiency of the kettle, according to an average estimate, is only about 80 per cent. Therefore, the above cost would be increased to 2.6, 5.2 and 7.8 cents, respectively.

Energy required to boil water and cost of operation at various rates per kilowatt-hour. Initial temperature of water, 60° F. Efficiency of apparatus, 85 per cent.

What Electric Cooking Rates Should Permit. — If the fundamental idea is that of exploiting electricity as a cooking agent in the 20,000,000 odd homes in the United States, associated with it ought to be the fact that the only effective means of competition, of capturing territory, will be the cost of such a system. It may be a philosophic theory that a thing is what its inherent force makes it, but experience at least has taught the world that business conditions are a form of warfare. The weapons are system and capital, to which may be added as corollaries, quality and competition. It is impossible to escape the view that general laws govern results in business life, as where the play of definite forces otherwise act. Where a certain innovation is presented as possessing superior qualifications over existing systems accomplishing the same result proof must be supplied. However backward the world has been, to-day it is developing marked rationalism. It accepts nothing for granted in certain spheres unless indubitable proof affirms the truth. Where competition between great public service corporations is being bitterly waged, where the lighting field is being torn from the grasp of one, the other field, that of cooking, will be as desperately held. Gas companies are losing their power to hold superiority in lighting only because quality and cheapness have compelled them to yield. If quality and cheapness operate in the heating and cooking field, the same phenomenon will be witnessed.

TABLE

ENERGY REQUIRED TO BOIL WATER AND COST OF OPERATION AT VARIOUS RATES PER KILOWATT-HOUR. INITIAL TEMPERATURE OF WATER, 60° F. EFFICIENCY OF APPARATUS, 85 PER CENT. ONE PINT OF WATER

Total Temperature Reached Fahr.	Watts Used for Minutes				Cost in Cents with Electricity at given Rates per Kw.-Hour			
	5 min.	10 min.	20 min.	60 min.	3 cents	5 cents	10 cents	20 cents
100°........	173	87	43	14.4	.04	.07	.14	.29
150°........	390	195	97	32.5	.10	.16	.32	.65
175°........	498	249	124	41.5	.12	.21	.41	.83
200°........	606	303	152	50.5	.15	.25	.51	.01
212°........	658	329	165	55.	.17	.27	.55	1.10
ONE QUART OF WATER								
100°........	346	173	87	29	.09	.14	.29	.58
150°........	779	390	195	65	.19	.32	.65	1.30
175°........	996	498	249	83	.25	.41	.83	1.66
200°........	1212	606	303	101	.30	.51	1.01	2.02
212°........	1316	658	329	110	.33	.55	1.10	2.20
ONE GALLON OF WATER								
100°........	1385	693	346	115.5	.35	.58	1.155	2.31
150°........	3117	1559	779	260	.78	1.30	2.6	5.2
175°........	3983	1992	996	332	1.00	1.66	3.32	6.64
200°........	4849	2425	1212	404	1.21	2.02	4.04	8.08
212°........	5265	2632	1316	438.7	1.32	2.19	4.39	8.77

Electric cooking rates should permit the effects of competition to become manifest in a marked manner. As regards quality of service, it would be stupidity to question its vast superiority. Gas efficiencies are not readily comparable with electrical. The only point is that of cost. The cost of heating a gallon of water to the boiling point at 3, 5, 10 and 20 cent rates mean 1.32, 2.9, 4.39 and 8.77 cents for charges. No one doubts the superiority of service, only the costs make them falter in certain localities where the rates are held. If competition is to be the spirit of business, a vast amount of business can be picked up by the adjustment of rates for cooking to meet those which make people regard gas-cooking as so much cheaper.

CHAPTER XXIV

DISTRICT HEATING FROM CENTRAL STATIONS

Central station heating is one of the most interesting problems to be considered by the engineering fraternity to-day, at least if the engineer considers the conservation of the fuel supply of the country, and by this means a pound of coal converted into heat units can be made to do the most work, furnish the most comfort to the people and the largest profit to the supplying companies.

Have we, as engineers, in the past measured up to the full standard of our responsibilities when commissioned to design and build the most modern power houses possible to obtain the greatest amount of power from a ton of coal delivered at the bunker? We have aimed to use our best judgment in design and lay out the most modern type of boiler plants with all the auxiliaries, such as coal and ash handling machinery, stokers and fuel economizers, keeping in mind the 10,000 or more heat units delivered to us originally in the pound of coal. We have installed weighing devices for both coal and water and recording gauges for every purpose that would help the operating engineer to know just what the power house was doing every hour.

We have seen to it that all steam pipes have been protected by the best covering, to minimize the loss in transmission of steam from boiler to prime movers whether it be a reciprocating engine or a turbine, all with the idea of producing electric power with the least amount of fuel, and what do we find as the result? The engine or turbine transforms from heat energy into the form of electrical energy considerably less than 35 per cent. of the heat units contained in the pound of steam delivered at the throttle or inlet valve. If this statement be true can we consistently say that we have reached a point in engineering design and construction that cannot be improved? Are we still to go on recommending large expenditures of money to do just what too many have been doing in the past, and trust that the business manager will never find out that we designed, built and turned over to him to operate, a steam or energy factory that will waste 65 per cent. or more of all the value of the fuel delivered at the plant?

Can we change the conditions that will conserve this great waste of heat? Can it be done, and how? To the first part of the question, Yes. It is being done in several hundred central station heating and power plants in the United States and Canada to-day. The latter part of this question will be answered in the affirmative when and wherever you gentlemen measure up to your profession and take a step forward, recognizing the conditions to be met, ever mindful of the financial results that can be obtained from what is usually considered a by-product, exhaust steam.

There are few cities of any size in the United States where the generation and sale of electric current is vigorously pushed, that a steam heating plant would not be a profitable investment, either in supplying live steam from a boiler plant erected for that purpose, or more preferably in connection with the central station now in operation that could sell all their exhaust steam seven months or more in the year and supplement any additional requirements with live steam.

In the electric plant having no heating system to operate, it makes no difference how low the water rate may be per kw.-h., turbine or engine, the fact remains that all the cost of coal consumed in producing the steam used must be charged to the generating cost of the station output.

From the conservation standpoint the steam now condensed may be diverted to heating business with an attendant financial result that very often pays the entire fuel cost and boiler house labor for twelve months, and in addition, interest and depreciation on the investment for steam mains.

It is obvious from an engineering standpoint that the ideal arrangement of operation or power stations, would be to exhaust into low pressure heating mains for the period of time covered by the heating months, and operate by condensing the balance of the time.

By this arrangement electric power will be produced at the least cost when exhaust steam is being sold, and at minimum cost that part of the year when no heat is required.

Engineers of Wisconsin: having no coal within the borders of your state and a limited amount of water-power available, wherein can you point out the way to furnish cheap power for factory purposes in competition with more favored states, unless it be from obtaining the greatest amount of the value from the raw material (coal) which you must ship from other states? In no other way can electric power be more cheaply produced than through the medium of the sale of exhaust steam. The writer makes this statement advisedly from experience (in the generation and sale of light, heat and power, in competition) with water-power transmission companies. The central station company that can furnish heat in conjunction with electric light and power need have no fear of competition from transmission companies for the reason that any price named by them for electric power, plus the cost of heating a factory or building separately, leaves a good margin of profit to the central station company that can supply both heat and power.

The engineer who serves his client best will no longer be charmed by the mystic words, "higher pressures, superheat or condensing," but will rather turn to the much neglected field of opportunity, where he may realize that the real commercia value of a ton of coal does not lie entirely with th.

small amount of electric energy it has produced, and will accept the ways and means at his command for utilizing for profit as much of the latent and sensible heat still remaining in the product of the original ton, namely, exhaust steam.

Some of the factors to be taken into consideration when laying out an underground distribution system for steam heating are as follows:

The amount of space to be heated in each block, the factor of maximum demand and the proportioning of the sizes of main supply and branches to give the required amount of steam at periods of maximum demand, and of sufficient capacity to furnish at least a pressure of one pound at the service valve of each customer with five pounds pressure at the power house.

Care as to the kind of insulation to be employed and its protection from all the elements that are found in the soil below the surface of the streets, multiplied by the numerous gas, water and sewer lines with their attendant leakage where they run parallel to, or across the steam mains and service lines.

The method of installation and its protection must be of such a character that settlement of the trench or the pressure of the earth will not cause the pipe to become out of level or alignment, as the pipe must have easy movement between expansion devices or else undue strain on such devices will cause breaks and leaks. The outer covering must also be of such a nature that expansion and contraction of the pipe within and the changes of temperature between that of the earth and the pipe itself will have no bad effect on the material used, otherwise cracks at the joints if it be tile, or concrete, permitting the circulation of air and seepage of water, not only causing excess condensation within the main itself, but a rapid deterioration of the pipe.

After more than thirty years of trial and with a record of 90 per cent. of all the central station plants in existence, to its credit, white pine casing or wood log has been found to be by far the best class of insulation and protection to underground steam mains.

The material from which the casing is made must be of selected white pine, free from sap or knots, thoroughly kiln-dried before being machined, built of segments not less than 4 inches thick, and after being spirally wound with extra heavy steel wire under tension, and the outer surface thoroughly impregnated in a hot asphaltum bath. The sections must have mortise and tenon joints and when being made up in the trench, the joints must have a coating of hot compound. It has also been found good practise and is a general rule that the pipe must be wound with two thicknesses of asbestos paper held in place with copper wire allowing a 1-inch air space between this covering, and the inside diameter of the casing, with collars placed against the ends of casing at stated points, thus furnishing a dead air space with its well-known insulating qualities, in addition to that of the 4-inch wood tin-lined casing. This class of insulation and protection to the pipe itself in conjunction with the rollers and guides upon which it rests, allows a free movement of the pipe within the casing.

Various devices have been tried for taking care of expansion and contraction of steam mains underground. Expansion or slip joints are used to some extent on long runs of pipe where service connections are not required; the use of fibrous packing with this kind of device, with the liability to leak, requiring service to be interrupted for repacking, makes the saving in first cost of construction of this kind of doubtful value.

In what is known as a variator where all joints are metal to metal, the necessary flexibility is secured through the medium of annealed copper diaphragms, which method meets all the requirements for expansion and contraction and requires no attention after once in place. The variators enclosed in water-tight compartments, without manholes, reduces the condensation losses of this part of the system to a minimum.

The method of service connections are provided for, every fifty feet of line from the outlets on the top of the variators or the anchor special located equi-distant between variators. The same care and manner of construction should be followed out in laying services whether at the time the main is laid or at any other time thereafter, as it is as necessary to preserve the same alignment, grade and underdrainage of the service pipe as it is for the main itself.

It may be said that the cost of construction of this type would seem excessive compared with other types and methods proposed that have not been used a sufficient length of time to prove their value, but when you consider that the extra cost of first-class construction wherein there is certain transmission losses, as there is even in the case of electric distribution, the very best methods are none too good, so it is as to the first cost of underground steam mains. The saving in first cost may very soon be used up in condensation losses, which are constant regardless of the amount of steam transmitted; therefore, the best method to reduce line losses to a minimum for the greatest period of time is the cheapest in the end, measured by the financial results, that are and have been obtained through many years of successful operation of some of the oldest central station heating plants to-day, using the type of construction as outlined above.

CHAPTER XXV

THE ADVANTAGE OF FARMING BY CENTRAL STATION POWER

The Problem of the Farmer. — There are many problems that confront the farmer. The first and most important is to live. He must get a living out of the soil by the power of his mind and muscles. If he can acquire a surplus over his needs he is a happy man. In some cases there is a reason why he cannot. In other cases it is sheer ignorance that prevents him. There are other cases of failure to properly and fully produce, due to laziness, carelessness, and bad judgment. But it is evident, to-day, that farming is a business. It is a producing business the same as any other industry. Known elements are employed to obtain a result. The soil, the sun, water, labor and skill are the chief ingredients. The problem of the farmer is to unite these things, to give him what he wants. And it is evident, that he must so relate these things, to that which he wants, that it is produced with a minimum of expense, time and labor. Therefore it might be stated explicitly, that the farmer's greatest problem is not in producing, but in producing most cheaply. It has been noted in all businesses to-day, by the "system experts" employed, that the percentage representing the cost of doing business is rising, has been rising for many years. This is due to "overhead" expenses, associated with each particular kind of business. These expenses would swallow up the business in many cases if it were not for the aid of scientific inventions, implements, necessities, things now accepted without a protest, which were once disregarded by conservative men and treated with contempt. The telegraph, the telephone, the typewriter, the auto-delivery wagon and auto-truck, have become established arms of the business world. They save labor. They save time and money. They facilitate the doing of all forms of business more satisfactorily. And this is what the farmer must do. He must save time, money and labor, by employing the means, the power obtainable to produce more with less effort, and devote his skill to enriching his soil. This, in factory parlance, means the improvement of the plant. The soil is the producing machine, and its enrichment is equivalent to its extension over greater boundaries. By employing electricity on the farm this is readily made possible.

The Horse Versus the Electric Motor. — As a power producer, where does the horse stand? Let it be considered as a machine consuming a certain amount of fuel, taking a certain amount of care, time and risk, in comparison with another machine. At present farm power is expensive, because the fuel costs are high. A good work horse represents an investment of $150.00, and such a horse is good for ten years' work if nothing happens in the way of accidents or ill-luck; and on this basis, the cost of animal power is several times the cost of electric power with the disadvantage of having feed bills when no work is done. A one horse-power motor will give 33,000 foot pounds a minute without weakening or slowing up. Its safety factor will permit an overload of from 25 to 50 per cent., without danger of destruction. A horse cannot stand a heavy strain like this day by day unless it be of unusual stock. Out West, a horse-power of electricity per annum costs from 2 to 4 cents an hour. It is a work of education to present the power problem to the farmer, to show him that he is already a consumer of large amounts of power, using animal power and manual labor at costs which are prohibitive when electric current is available. It costs $7.00 a month for seven months to feed a work horse if the farmer has the feed, and if he has to buy the grain and hay, the cost will be increased to $10.00, with $3.00 a month for the other five months. Aside from the feed is the care of the horse. This takes time and labor and costs money. In a city this cost is clearly expressed by livery or stable charges. At least $30.00 a month is thus allowed. In the country the cost for feed is less, but the labor is there. Consequently it is worth $15.00 a month at least, to feed and care for a horse on the farm. This is 50 cents a day every day of the month, or for 26 working days about 58 cents a day. Now a horse-power of electricity per day, at 2 cents per hour of 12 hours, costs 24 cents. At 3 cents per hour, a day costs 36 cents. At 4 cents per hour, a day costs 48 cents. This is a saving of 10 cents a day, or $3.00 a month at full power, with no special care required, no stable, no cleaning and little risk.

The Farmer's Failure to Make Money. — Now considering a farm as one would any other business proposition, why is it often a life of drudgery? The answer is not difficult to find in the statement that if a farmer can get returns of a thousand dollars a year, paying hired men from $20.00 to $50.00 a month, he is often satisfied. Saving this amount is possible if the farmer is a man of unusual strength and skill and good business ability. The tug of war is between the soil and the man, and the battle is a severe one on almost all occasions considered. Sometimes the soil is virgin and full of vitality. The crops are plentiful and the weather propitious. But the danger of frost and rainfall, wind and hail, are ever present in the farmer's mind. The evil of insect life, of parasitical diseases, of marauding animals and sometimes human purloining are also possible and frequent drawbacks. But aside from these things, the farmer does a lot of unnecessary work, and weakens himself by overexertion in many cases which might be recorded. The idea presented is that the farmer overdoes his work. He could use machines as other modern industries do, and be as up-to-date in his work as the necessity requires. If a crop must be gathered quickly, electricity would give light at night.

Where high pressure work is a necessity a night force would pay as well in farming as in other businesses. In other ways it is evident that the attempt to do things requiring great strength is not practical, because it deadens the brain to use the muscles exclusively. The need for motors on the farm to do many of the odd jobs would mean more of a directive or executive than a laborer's position for the farmer. The night in the home would be brighter and devoted to higher thinking. Planning cannot be intelligent or effective if the senses are stupefied with excessive labor all day. These are a number of the things to be done on the farm by electric power: Ploughing the field or treating the soil in any way requiring power. Cutting and grinding feed and transporting it from place to place. Sawing wood and preparing it for kindling, or for logs as desired. Supplying plenty of water to the house, barn and stables as needed. In addition, or as a separate and fundamental purpose, pumping water to irrigate the entire farm. Churning and separating cream or doing other special dairy work. Compressing hay for storage for winter use by means of presses. Milking cows, clipping horses if they must be used, and washing clothes. One of the best jobs a motor can do is to thresh. In the Miami Valley is a farm owned by Mr. Stroop, the crop of which was threshed successfully by electricity.

Threshing by Electricity and Its Advantages Over Steam and Gasoline. — The threshing on Mr. Stroop's farm was usually done by Mr. Elmer E. John, by means of a 33-inch Peerless separator. When ordered, he brought to the farm his big traction steam engine and set it up for business. At full capacity, the separator used up all the power his engine developed. Mr. Stroop, however, had been using an electric motor about his farm buildings for cutting and grinding feed, sawing wood, etc. He was connected with the high tension lines of the Dayton Light and Power Company. The motor had been shifted to various positions as desired and the connections made with very little trouble. The motor was capable of developing about fifteen horse-power, but demonstrated upon occasion that it was perfectly capable of developing much greater power. When Mr. John was asked to use the electric motor on the job instead of the big engine he readily consented. But his engineer was incredulous about that small motor running the big separator at full capacity. The machine was set and the belt adjusted. When the power was turned on and the wheels started to go around, and the sheaves disappeared, and the grain began pouring out, it was demonstrated that the power was sufficient. The men in the mow worked faster and faster in order to test the capacity of the little motor which was set back in the barn right against the side of the mow. It hummed almost inaudibly, and as the sheaves fell more rapidly into the machine and the separator was forced up to its full capacity, it pulled away steadily without diminishing its speed. Hour after hour the work proceeded without stopping, and when the job was finished it was found that in less than twelve hours more than seventeen hundred bushels of perfectly cleaned grain had been threshed. It was the first time, as far as known, electric power had been used for threshing grain in the Miami Valley. A new era had dawned in agricultural science, full of promise for the farmer, who can obtain the necessary power from a reliable source. The experiment demonstrated the practicability of using electric power for the heavier work of the farm. It is used on the Stroop farm for every purpose where power is required. It takes the place of the gasoline engine, is far handier and less expensive. The initial cost is low, the price of the one used in the experiment being two hundred and fifty dollars. Considering the cost price, the remark made by Mr. John, the owner of the thresher, that the cost of threshing would be materially reduced if such power were available everywhere, can be readily appreciated. It would do away entirely with the steam engine and its cost of nearly two thousand dollars. It can be operated far more cheaply. The cost of fuel for the engine is eliminated and as no engineer is required, the wages of that individual can be saved, and saved to the farmer. The motor works away without any attention whatever, except an occasional oiling. Probably fifteen minutes a day will be all the time required to care for it. If the cost of the engine could be greatly reduced and the expense of maintenance cut in two, steam power would pay. But where electricity is available it is easy to see where the farmer is benefited by using it. It cannot be obtained on all farms, but it is known that the power companies would make the necessary connections and furnish energy for lighting and running all kinds of machinery on the farms contiguous to their lines. This seems to be the new outlook, the latest in engineering, the electrification of farms.

Electrically Operated Farms in Colorado. — At a meeting of engineers in Seattle recently, C. H. Williams surprised most of his hearers when he told them that the electrical companies of Colorado were doing a large business with the farmers. The most important use to which current is put is in the driving of pumps to supply water for irrigation. When the crops are gathered the farmer cuts and mixes feed for his stock with electric motors. In the barn he installs an electrically-driven exhaust fan to obtain proper ventilation. In winter electric cuffers or vacuum cattle cleaners are in use on many dairy farms, while electric vacuum milking machines are superseding the trim dairymaid of popular imagination.

The milk house is equipped with a five horsepower motor belted to a line shaft, to which are connected a small refrigeration plant, a cream separator, a butter churn, bottle washer and grindstone.

The troublesome and to some extent dangerous oil lamp has been succeeded in the house by electric lights, and on some farms the kitchen work has been further lightened by the substitution of electric flatirons and stoves. Among the prosperous farmers electric autos are in general use.

Electric Irrigation Reclaiming Millions of Acres. — Agriculture cannot be carried on in any country whose annual rainfall or precipitation averages less than twenty inches. The only possible way to accomplish the work otherwise is by means of an artificial supply. East of the Rocky Mountains are lands aggregating three hundred millions of acres, lying between the limits of Canada and Mexico. They are in themselves, in this respect, one of the greatest problems with which scientific agriculturalists have had to deal. Everything that lends itself to success is there but water. The area is equal to 470,000 square miles, possibly half a million in all. The soil is deep and fertile, the climate healthful and agreeable, and other conditions are ideal. Wyoming and Colorado cover a heavy percentage of this territory. For a distance of 100 miles east from the mountains there is a limited precipitation of about 14 inches per annum. In the mountains it is greater because of the damp, moisture-laden winds coming in contact with the cold mountain peaks which condense and precipitate the vapor in the form of snow. Reports from the Cache La Pondre River basin, one of the important streams in Colorado, show that 65 per cent. of the rain falls during the growing season. In the mountains the opposite is true. There the snow falls from October to April and lies in storage for the late spring when it begins to melt and continues during the summer.

Irrigation projects, for the purpose of using this congealed watershed were tried. In irrigation work either the gravity or the force pump system are employed. The gravity system, that of depending upon the natural flow of the water down a slight declivity, is often impossible. Ofttimes the losses in this way are enormous, because when ditches are built, by excavating in the loose soil and throwing the dirt upon the sides to make embankments, it is difficult to admit sufficient water at the headgate to obtain a run at the lower end. Therefore there is only the means left of digging wells, and distributing the water by pumps. This has resulted in the development of electrically-driven pumping plants drawing their water from artesian wells. The cost of a typical pumping plant complete, for which the farmer makes an investment to supply water to a 160-acre tract is $1,156.00, or $7.23 an acre. By this he is made more independent than the farmer in more temperate climes. He waters his crops at will and has no occasion to worry over droughts.

How Wells Are Dug. — The well diggers cannot guarantee water when they dig, so they ask to be paid by the foot of depth. But well-digging companies have formed in states contiguous to this dry territory, particularly Wyoming and Colorado, who offer to all land-owners guarantees. These are the outgrowth of the power companies enterprise. They agree to put down wells and produce a certain amount of water, no charge being made if they do not supply the water in a quantity as contracted.

Centrifugal Pumps. — The pump meeting with the greatest popularity and success in Western irrigation work is centrifugal. They are more in use than all others combined. They are made to operate by either vertical or horizontal shaft to suit conditions and of a size to extract hundreds or thousands of gallons an hour from the well. This means a stream of from one inch diameter to 20, 30 or 40 inches or more, and an elevating force sufficient to raise the water from a few inches to hundreds of feet. They are constructed to assist each other, the discharge of one helping by suction to operate the other. Such types are called compound, to distinguish them from the simple forms.

The Reliability of the Electric Motor. — Gasoline engines and windmills are no longer in vogue as a general thing in these districts. The electric motor has superseded all. It always runs when wanted and requires less care than any form of available power for this work. Practically one-half of all the motor installations in northern Colorado have supplanted engines, and there has never been a single change by which the motor has been displayed by any other form of power, nor has there ever beeen an electric pumping plant installed which later was discarded. When the motor is started, the pump house is closed, and the farmer goes about the work of distributing the water in his fields and provides no further attendance for his plant. The farmer by experiment and practical test has discovered that well water is often better than stored water. In two adjacent potato fields in northern Colorado, the one which took water from the reservoir lost its crop, realizing only five bushels to the acre. The other, which pumped water from a well, secured a yield of eighty-five bushels to the acre. Both were 160-acre tracts and similar with the exception of the water. In the section spoken of, the cost of perpetual water rights for a 160-acre tract according to contract is $7,533.00. Interest on this with maintenance and other charges bring the cost of water per acre up to $5.85 per season. An individual electric plant costs but $2.47 an acre. One manager of a large sugar factory finds it pays to incur an expense of from $8.00 to $12.00 an acre a season in raising sugar beets, and he is now putting in a large number of deep wells to irrigate 37,000 acres of beet land.

CHAPTER XXVI

STEAM IN CENTRAL STATION USE

What Is Steam?— They define steam as a gas due to the heating of water to the boiling point. It is invisible, though the popular misconception is that it is visible. What is visible is vapor, or steam that has been condensed. Steam in itself is the result of a high temperature being applied to water. According to the most modern theories heat is a mode of motion. When there is no heat, there is no motion. A condition of quiescence or motionlessness, otherwise called immobility, means no molecular vibrations or motion. Water means a constant change in a molecular sense of the contiguous elements that are still water, that compose it. The molecule subdivided means oxygen and hydrogen. Sufficient heat will reduce or decompose the water into these two elementary gases. But each water element is composed of these gases, though it will remain water until forced to disintegrate. The molecules are shooting back and forth with incredible rapidity. A certain number shoot beyond the surface of the water, breaking the "skin" as it is called. The number that do this depend upon the degree of agitation of the molecules. This agitation depends upon the degree of the imparted heat. Heat, as thus measured in degrees, with respect to water, indicates the amount of molecular motion. When the water is becoming heated by convection, or the rising of the heated water to the top and the falling of the colder to the bottom, the molecular agitation is also increasing in intensity. The water molecules are shooting upward with tremendous velocity. The action of a jet of steam on a piston is like that of a set of Gatling or Maxim guns in miniature. The steam acts like a volley of projectiles. It also acts like an expanding cushion. Each molecule tries to get as far as it can from its neighbor. Thus there are two things happening: the projectile force and the repulsive effect. One is called the kinetic and the other the expansive force. Each adds its quota to the development of power in the engine. How many millions of these infinitesimal particles are acting each time the piston moves can be but roughly estimated. The aggregate number must be billions upon billions, but each one imparts its energy of motion and expansive force.

The expansive force is what is relied upon to develop the best efficiency. The impact of the molecules delivers the main element of power. After that is accomplished expansion sets in. Herein lies the difference between the steam turbine and engine. The impact of the steam jet does most if not all of the work in the turbine. The kinetic force and expansion of the steam delivers the power to the engine proper. As expansive force is gained in the turbine a higher efficiency results, but the main efficiency is the result of a relationship between the peripheral speed of the turbine vanes and the initial velocity of the steam. It is obvious that, if the vanes or buckets of the turbine moved at the same speed as the gas particles in the steam jet no power could be communicated. To obtain power, the steam would have to strike a surface moving slower than itself. For instance, a bullet moving 90 feet a second would produce no effect if aimed at a train moving 90 feet a second. But if the train is moving 45 feet a second, a bullet striking it would not produce the impact equal to that due to a train at rest. It would be much less on account of the motion of both. As the motion of one is greater with respect to the motion of the other more power is delivered. But the wheel of the turbine moves swiftly, and for that reason the steam pressure must be great enough to give the steam as much higher a velocity as will serve to contribute to a higher efficiency. Thus, the study of the problem of steam from a molecular standpoint has a direct practical bearing on central station service with respect to the turbine and engine.

The Different Kinds of Steam. — There are several kinds of steam, named according to their physical characteristics. These characteristics depend upon the conditions under which steam is made. It is not always made the same way. By this is meant that there are three or four kinds of steam boiler-made as it were, yet each kind is different and produces different results. In a general way it may be said that there are two kinds of steam; wet and dry steam. What is called steam by the layman, that is to say, the visible manifestation of water in vapor form is called wet steam. Wet steam is steam containing moisture appearing as a vapor, mist or spray. It is actually wet when it first appears, whereas dry steam is different. Dry steam is steam that is as its name implies perfectly dry. It contains no moisture and can only display vapor when cooled. These two generic conditions cover some other forms of steam. For instance, dry steam is steam which may represent superheated or dry saturated steam. There are distinguishing differences between these which require analysis, and then recapitulation of the whole as follows:

I. *Dry steam* is steam which is free from water particles in any form representing mist or vapor.

II. *Wet steam* is steam which contains moisture in the form of vapor, mist or spray.

III. *Saturated steam* is steam that differs from either in that the temperature of the steam and the water remain constant. This condition of affairs continues until all the water has been converted into steam, the temperatures remaining the same throughout. When the last of the water is gone and only steam remains another change occurs which develops another type of steam.

IV. *Superheated steam.* With the evaporation of the water the steam does not remain at the same temperature, but rises. This rise of temperature with the steam remaining at the same pressure produces what is called superheated steam. According to an authority, saturated steam is steam of the temperature due to its pressure, not superheated. Superheated steam, however, is steam heated to a temperature above that due to tis pressure.

Concussive Ebullition. — A term employed in engineering is concussive ebullition, or the ebullition of a quantity of water with explosive effects. It is noticeable in those cases where superheated steam is made to act upon a small quantity of water in low pressure receiver. A common example is the concussion in a steam radiator when steam is admitted. In those cases where the boiler is subjected to intense heat and the pressure becomes high, the water rises in temperature to a point where it would instantaneously form steam were the pressure upon its surface removed. Were it possible in such a case to suddenly condense the steam above the water line, there would result at once an upheaval in the water thus overheated. It would tend to fly into steam with explosive violence. Thus, the slack of the water body would be comparable to the ignition of a powder charge. But the difference would be in the fact that the potentiality of the charge would be found in the pseudo-water in the boiler. Though water, it is really steam held in liquid form by the pressure above it. In this manner explosions are suggestively explained.

Boiler Explosions. — The wrecking of a boiler is due to the fracture or failure of the shell. The shell fails because of a shear or stress beyond the power of the shell to resist. The riveting may be responsible for this, or the plate may be burnt in the fire box, grow thin and collapse. The boiler may deform due to the insufficiency of the stays. Old age may weaken it to the extent of making a general wreck of it. Whatever the case may be, the conditions lead to its destruction and what is called an explosion ensues. As regards this ultimate fact, the hypothesis here advanced, is to the effect that concussive ebullition plays a large part in its destruction. The reason why this is presumed is that the shell fails at a time when the water is so heated that were it able it would instantaneously form a vast body of steam. The break in the shell supplies this opportunity. The water within instantly explodes. The boiler responds to the impact of this hurled mass of water and an explosion, so-called, results. Placing one hand on a radiator in which concussive ebullition is transpiring, is excellent proof of the severity of the shock. In the case of a boiler being wrecked, the rent or rupture permits the steam pressure to suddenly drop; the water is precipitated into a low pressure medium; it expands with the rapidity and force of dynamite; and the result is catastrophic. Any other form of boiler explosion would be moderate in comparison. A case of some similarity is that quoted, "water introduced into the presence of superheated steam will flash into a vapor until the temperature of the steam is reduced to that due to its pressure." This is a case of water pumped into an empty boiler apparently, as far as practise is concerned. But the explosive force is naturally proportional to the mass of the explosive, therefore with a small quantity of water, as long as the boiler does not lose its rigidity, does not fail, in other words, the sudden transformation of the water into steam would not be sufficient to wreck it with destructive results.

Latent Heat. — Heat that is absorbed is latent heat in the broader sense of the term. When steam is being made, the water is absorbing the heat in much the same manner as a sponge absorbs water when dipped into it. The water possesses this quality to a marked degree, in fact, much more so than any other fluid in existence. The temperature of the water remains constant after the boiling point is reached. The steam remains at a constant temperature during the process as well. There is no change in temperature, even though the heat is being systematically added. This heat disappears in the form of molecular change of position. It is called latent heat. When the steam is condensed, the latent heat is given out again. The amount of heat absorbed, or becoming latent, as water is changed into steam, will become less in proportion to the increase in temperature of the steam during formation. The power thus absorbed by water in contact with heat is the power utilized in creating rotary motion in the engine. The process is, therefore, a simple one: the combustion of the coal chemically creates the rise in temperature; the heat of this combination is transmitted to the water in the boiler. The more of this that is absorbed by the water, the more of it will be given out by the steam. The water is the medium of exchange. It is the means by which the energy of chemical change is converted into rotary motion in the steam engine. The latent heat is given out when the steam expands and condenses in the cylinder. Thus, the loss in energy, is that due to the lack of expansion in either steam engine or turbine. It is considerably less in the turbine than the steam engine. But the molecular forces at work — those of kinetic motion or impact, and those of expansion due to the repulsion of molecule for molecule — are the mediums of transmission of energy. The mechanism employed is not more important than the supervening conditions in the steam, that lead to efficiency and output. It becomes a question of boiler, engine and molecular forces.

The British Thermal Unit. — The bond of relationship between work and heat is found in the value of the British Thermal Unit. Heat is a form of vibration. Joule organized the data which led to the fundamental proposition — that heat is a mode of motion — that the mechanical equivalent of heat is measurable. According to Charles L. Hubbard the following is true: "That branch of science which considers the relation between heat and mechanical work is called thermodynamics. It deals with the numerical relation between the quantity of heat used and the amount of work done. We have already seen that heat is produced by hammering or distorting a body. Other examples of the generation of heat by work are found in the bearings of machinery, cutting tools, etc. In the steam engine hot steam is admitted to the cylinder, it does work on the piston and is discharged cooler than it entered; heat has disappeared and work has been done. It is plain that when work is done on a body heat is generated in it, and when work is done by a body some of its heat disappears. Experiment shows that when a certain amount of work has been done by a hot body a corresponding amount of heat has disappeared. This subject has been investigated with great care, and it has been found that the ratio of the unit of heat to the unit of work is constant. That is, if 778 foot pounds of work are done on a body, enough heat may be generated to raise the temperature of water one degree Fahrenheit. This equals one British Thermal Unit. Conversely, if a hot body — steam for example — does work, one B. T. U. will disappear for every 778 foot pounds of work done. This number 778 is called the heat equivalent of work or the mechanical equivalent of heat." Thus thermal vibrations called heat are expressed in their full mechanical equivalent of working energy. The entire phenomenon seems to be that of motion, which is imparted through chemical combustion and then transmitted. The general effect is that of transformation. The elements through which the transformation occurs are chemical and mechanical. Fire produces the original vibrations, and these are imparted to the boiler, thence to the engine and finally, as in central station service, to the generator. But the generator does not end the process, for the vibrations actually become visible in a transformed type as light in the incandescent or arc lamps.

A recapitulation of steam thus shows that its practical aspect is not out of touch with the conclusions of theory. There are new theories arising every day, but those that stand the test of time and experience are the ones we cling to for safety's sake. "There have been many theories in regard to the exact nature of heat, but the accepted one at the present time is that of molecular vibration. It is thought that heat is a vibration of the molecules of which a body is composed, and that the degree of heat, or temperature, depends upon the velocity and amplitude of the vibrations. What is called temperature, or the intensity of heat, is simply a measurement of the velocity or speed of vibration of the molecules. The thermometer simply indicates the intensity but not the quantity of heat. A flat-iron may contain more heat than a lamp filament, but show no outward evidence except in diffused warmth. A lamp filament may be incandescent, showing a higher temperature, greater intensity, but much less heat. This is where the units of heat may be considered in a practical manner.

Specific Heat. — As far as water is concerned, its specific heat is greater than that of any other fluid or substance in existence. This has already been stated. For that reason water is the only fluid that can be successfully applied to our present system of power production from heat. The thermal capacity of a body is its absorptive power for heat. The capacity of a pound of water to absorb heat is thus the foundation of the present system. Other bodies are measured with reference to it. Could another substance be found that would absorb more heat than water, provided the price was not prohibitive, it would receive attention and test. The thermal capacity of one pound of water is one British Thermal Unit. That of other substances is less than one. This all means that a pound of water can store up more heat vibration than a pound of alcohol, acid, gasoline or any other mentionable fluid.

According to Hubbard, in his work on Power, Ventilating and Heating the following is true: The properties of steam with which the engineer has most to do are given in what are called a steam table. Referring to this we find the following headings to the different columns which compose it:

1. Pressure in pounds per square inch.
2. Temperature in degrees Fahrenheit.
3. Heat in the liquid above 32° F.
4. Internal latent heat.
5. External latent heat.
6. Latent heat of evaporation.
7. Total heat of evaporation.

8. Weight of a cubic foot of steam in pounds.
9. Volume of a pound of steam in cubic feet.
10. Ratio of volume of steam to volume of equal weight of water.

Each of these items requires particular consideration in a review of steam and its functions. The boiler pressure for instance, is one atmosphere less than the recorded pressure. In other words the gauge pressure is one atmosphere of 14.7 pounds less than that recorded. This is because the medium in which we live is a huge ocean of air and at the bottom of it where we live the pressure or actual weight of the air, due to that above, is about 15 pounds to the square inch. The steam table is valuable in supplying data of use. From it, it is possible to find the temperature corresponding to a given steam pressure and the pressure corresponding to a given temperature. Another item of importance thus obtainable is the quantity of heat. The number of units required to raise a weight of water through a range of degrees to arrive at a given pressure is of direct interest.

In central station service a complete study of steam yields practical benefits. It gives the man in charge a sense of responsibility due to an inside knowledge of the nature of the case and this is the best type of man to put in charge of such responsibilities.

CHAPTER XXVII

THE MANAGEMENT AND CARE OF BOILERS

What Experience Teaches. — Every machine requires a certain treatment to make it give the best results. By this is meant that the handling of it teaches, through experience, what is the best thing to do and the best time to do it. This is true of all kinds of machinery, particularly after it, as Kipling says, "has found itself." In other words, machines have individuality, and the particular traits composing this must be known before the device in question will yield its fullest quota of benefits. This is found to be true of engines and boilers, and to a degree that affects the commercial standing of the article in the hands of ignorant and inexperienced men. Therefore, the best things to do are matters of experience and the best methods to employ in the handling of one or more boilers. As a means of general guidance it is known that there are a set of rules and regulations, things to do and things not to do, which must be known in the handling of boilers and by central station engineers or those learning the system in the central station.

The Water Level. — An engineer should know the true water level. There are two ways of ascertaining it: One by means of the water gauge: the other by means of the gauge cocks. The water tube or water gauge is a good indicator, but the fact that dirt may choke up the canals leading to the glass must be kept under consideration. The gauge cocks are excellent guides, however, provided no vacuum exists in the boiler. A vacuum may exist there if the boiler, which was full of steam, is absolutely tight. A boiler with no chance to have air enter or leave it will hold a vacuum when the steam within it condenses. Under such conditions the vacuum will hold the water even when a gauge cock below the water line is opened. In such a case as this, the water gauge shows a level of water in the boiler, yet when a gauge cock below this level is opened no water issues. The thing to do in such a case is to open a gauge cock above the water level and let the air enter the boiler and fill the vacuum, which will then permit the water to manifest its true level through the gauge cock below its level.

Before Starting the Fire. — The gauge cocks alone are not reliable; neither is the water glass gauge; but together as a means of checking each other they are guarantees of the condition of the boiler water. Before the fire is started it is good practise to see that any vacuum that exists is destroyed by opening the gauge cocks on the safety valve, and even though they are left open no harm will be done if they are closed, one or both, when the fire is started and steam is being made. In fact, it is good practise to get rid of a vacuum that thus forms by keeping the inside of the boiler in communication with the outside air until steam issues. There is then a certainty that the vacuum no longer exists, and that the air which entered to fill the boiler has also been forced out in its place. When the fact is established as to what the real water line is, the next thing to do is to test the safety valve by slightly raising it and thus seeing that it is quite ready to work properly. These precautions should always be attended to before starting the fire, otherwise danger arises or is apt to arise with respect to the water level or the action of the safety valve. Establishing and knowing the water level is essential to good practise.

Starting the Fire. — There are two cases to consider here: First, that of the fires burning; second, that of the fires being started. If they have been banked the correct thing is to carefully free the grate of debris, dead ash, clinkers, stones, etc., and then give the red ash bed a little life by putting on the draft. This is the best practise before putting on fresh coal. It is not difficult after the relationship of the drafts is known, that caused by the damper and the grate openings, to the rate of development of the fire. In some boilers the draft is very great and a slight opening of the lower grate doors is sufficient to blow a hot ash bed into a glowing heat. In other boilers more draft is apparently needed, because the final draft is not as great. If the fire is out, a thin layer of coal over the ash bed may be used to start a new one. Strips of wood are placed with their ends resting on each other over this to secure an air space. Shavings, oiled waste or tarry or resinous pine may be used to light up. After an interval coal is spread over this blazing surface and finally the draft is allowed to operate. One of the points to be observed is that the fire must be evenly distributed over the entire grate or a "lumpy" fire will result. A fire blazing hot in the front or back will mean uneven heating. This is particularly necessary to observe in the case of a cold boiler. Here there is a great deal of expansion and contraction under such circumstances. A uniform heat is the thing on all occasions, whether when the fire is started or after it is in full operation.

Methods of Firing the Boiler. — As a certain form of skill must be developed to handle a boiler up to the point of getting the fire safely and properly started, it is also true that another kind of skill is necessary to handle the coal after it is placed on the bed of the hot embers. Technically this is regarded and named from three distinct standpoints, as follows: First, alternate or side firing; second, spreading; third, coking. The particular details of these methods are thus noted:

1. *Alternate or Side Firing.* — By this system of firing the coal is spread on one-half of the hot embers at a time. When each firing is done only one-half of the fire has been covered with coal. The advantage of this system is theoretically acceptable and is to an extent acceptable practically as well. The idea is that the incandescent half of the fire bed

ignites, consumes and gives off the heat of the body of fresh coal undergoing partial volatilization. It is claimed that a system of this kind is particularly applicable to cases of two furnaces having but one combustion chamber. In such an instance, coal is applied to one furnace and then the other. The draft is permitted to operate alternately in one furnace and then the other until the gases are burned up. The whole problem in boiler handling and in firing is to economically use the gases of combustion. If they are allowed to escape without being properly burned and their heat absorbed, a heavy loss in caloric efficiency will result, even though other parts of the plant are perfect.

2. *Spreading.* — This method of firing is that of using a small amount of coal at a time and spreading it as thinly as possible and as evenly as practicable over the hot embers. One of the characteristics of such a fire is that it is so built up that it is thin in the center and thicker around the edges. The objection to opening the furnace doors very often is a valid one, because of the great amount of cold air that enters. It must also be noted that after coal is added air is needed to combine with the gases to produce complete combustion. The air inlets or drafts above the fire are needed in this case to let in the air required for the purpose. After the gases have been burned, the over-fire draft plates must be closed. A certain amount of skill of a somewhat high order is needed to properly adjust the drafts to obtain the maximum effect. Although a fireman

may not be regarded as an expert, still in his particular work he is or should be an expert. It is a matter of experience and judgment to correctly regulate a fire. The use of automatic stokers, forced draft and other skill and labor saving devices aimed to increase the efficiency of the plant do not dispense with the man and the brain that guides him. The two systems considered so far, the side firing and the spreading, are best employed with anthracite coal. When the fuel is of a soft character, bituminous, for instance, these systems are not to be employed, for reasons quite obvious.

3. *The Coking System.* — This method of firing a boiler is one brought on by the necessity of using the soft coal of commerce. It is tarry, smoky, gassy coal, which must go through a preliminary coking process before it is entirely useful. As one writer states: "When bituminous coal is used the coking system is to be preferred. In this case the coal is piled on the grate just inside the furnace door and is allowed to coke from 15 to 30 minutes in order to distill the hydrocarbons. These gases are burned by admitting air through the draft plates. After the coking process the mass is pushed back over the fire and fresh coal placed in front of the grate. The air admitted cools the furnace somewhat and reduces the rate of evaporation, but the objection is not serious unless the boiler must be worked to its fullest capacity in order to furnish the required amount of steam. The proper thickness of fire must be determined by trial and will depend

upon the grade of coal used and the available draft. In case of a strong draft and coarse coal, the fire may be about a foot in thickness, but if the draft is weak or the coal fine, the thickness should not be more than four or five inches. With forced draft a thicker bed of coal must be carried in order to secure a high rate of combustion. With the same draft bituminous coal can be fired more thickly than anthracite. After having determined by experiment the best thickness of fire to carry, it should always be kept the same. The rear of the grate should never be allowed to get bare and air holes in the fire should be covered over as soon as formed. If it becomes necessary to force a boiler, it may be done by firing smaller quantities of coal at shorter intervals. Never fire a large amount of coal and wait for the pressure to rise, for the introduction of fresh fuel chills the furnace and retards combustion. Keep the grates free from clinkers and ashes, but do not clean oftener than necessary." These simple rules sum up the firing of the boiler. That many other little things suggested by experience can be done will not be doubted, but the main idea is to keep up the pressure, use as little coal as possible, and keep the fire in the right condition by the use of science, experience and common sense.

Cleaning the Fire. — One of the first requirements before the fire is cleaned is to see that the steam will last for service while this is being done. This applies to the water as well, then the fireman is ready to begin operations.

1. The clinkers are removed from the grate bars by means of a slice bar and are broken up for removal.

2. The ashes are removed with a prick bar as conveniently and in as cleanly a manner as possible, but the disturbance of the fire should not be such that the hot coals are cooled too much and the fire thus endangered.

3. The fire should be pushed to the back and the grate bars in the front cleaned of all debris. Then the fire should be pushed to the front and the grate bars in the back thoroughly cleaned of all inconsumable matter. Or, the process can be carried out like side firing, by forcing the hot coals on one side, cleaning, and then on the other side and cleaning. After this is done the fire must be allowed to drop in brightness, but not too much or the banking will be ineffective. The dampers must be well watched and kept reduced to allow just the proper amount of air to enter or the chill of fresh air will cut down the steam pressure too much. In fact, the whole operation must be conducted with as much rapidity as possible to prevent the boiler pressure from falling too low. Therefore, the process consists of, first, sufficient water and steam to hold over; second, the cleaning of the fire; third, the correct handling of the draft; fourth, the preparation of the hot coal bed for the final banking of the fire.

Banking the Fire. — There are a few points to consider in the banking of a fire that call for serious consideration, as follows: First, the condition of the fire must be well understood before any of the usual things are done in the way of banking it. Second, the time the fire is to be left unattended must also be considered before it is prepared in the way it is supposed to be. Third, the way in which the fire is left is largely dependent upon that particular element of indescribable experience characterized as empirical by those endowed with sufficient psychology to understand its significance in this case. The process is generally that of cleaning the back grate bars and then pushing the entire fire in a heap against the bridge wall. The fire must be well heaped up, so that the combustion will be hampered, yet the ventilation not destroyed. The judgment of the fireman is then called into play to lay enough coal on the hot mass to last the number of hours required. The next point is to almost entirely shut off the dampers, except to the degree required to carry off the coal gas, and open the fire doors. In this manner the fire is made to last from day to day as long as the boiler is in use.

Starting the Fire. — When the fire is to be started again from a banked condition, the following points are noted: First, the steam pressure must be observed and the water level examined to see that there can be no fault found in this direction. Second, it is absolutely necessary to test the safety valve to see that it is in as good working order as it should be in service. Third, the ashes and clinkers must then be removed by means of the slice and prick bar, the fire thus being thoroughly cleaned. Fourth, coal is then spread over the hot embers evenly and thinly and the dampers opened for draft to let the fire glow. There is this to be said about the whole operation: The fire is banked not only to keep it, but to have it ready for making steam in the morning. In order that it may be in this condition, there are a few items to consider. In the first place there must be enough hot coals banked to provide a foundation the next morning for a good fire. The fire must be kept hot enough to stand the prodding and cleaning the next morning. There must be enough heat in the hot bed to quickly make steam when the fire is made. And, finally, the banked fire must hold and radiate enough heat to keep the boiler water hot and some steam pressure on tap. Otherwise the complete cooling will mean a great loss of time in the morning getting up steam. Such a condition of affairs could hardly be attributed to good practise, and in consequence, if often repeated, would necessitate changes in the management of the boiler room.

Ashes in the Pit. — The accumulation of ashes in the ash pit must not be permitted, for the reason that they will eventually burn the grate bars. The removal of such deposits is necessary, although some firemen meet this difficulty by having the pit damp or wet with water. Having a couple of inches of water in the ash pit will do no harm, and therefore the practise is to be recommended. Another feature is the advantage of a little steam in the fire. The heat, if high enough, will decompose it into its elements, oxygen and hydrogen. The oxygen will add to the combustion and raise the temperature, and the hydrogen will supply an individually hot flame. Blacksmiths have a habit of dampening the soft coal they use while it is being burnt for this purpose.

Inoperation of the Safety Valve. — If the safety valve does not blow off at a point to which it is set, it is advisable to act immediately and cut down the fire and the pressure. The pressure gauge should indicate zero when there is no pressure in the boiler, and if it does not, there is something the matter with it. The thing to do when the safety valve does not work is to bank the fire and test the gauges and the valve at once. Safety valves sometimes stick. When they do it is not right to operate the boiler, for the only positive mechanism of a protective nature between safety and explosion is this valve. It should be tested frequently, if it is in the habit of sticking, and thus made to supply some assurance of its reliability. The gauge cocks, glass water gauge and safety valve are the only indications of what is going on inside the boiler. There is a terrible risk in neglecting them on any occasion. The only other feature of protection may be a safety plug many boilers are built with. But the real protection is the safety valve and the gauges. Whether before or after the steam has been in use, these accessories of the boiler must be kept in a working condition by frequent testing. The safety plug or fusible plug must be cleaned and scraped every time the boiler is cleaned or the dependence placed on it in an emergency will fail. In fact, the boiler, as regards all such safety appliances, cannot be too well scrutinized while in use. The safety valve and pressure gauge leading; the gauge cocks and glass water gauge being second in importance.

CHAPTER XXVIII

INCREASING BOILER CAPACITY IN CENTRAL STATIONS

Advantage of Increased Capacity and Efficiency of Boilers. — If the increase in the capacity of a device is secured without a loss of efficiency, then the gain is that of having a smaller investment do what originally called for a heavier one. In addition, if the device is a boiler, the space saved, as well as the reduced labor liability, means a considerable advance financially. There is less real estate, or less cubic space, which in this or other cases is what real estate is supposed to secure, and a greater output obtained. As a writer puts it, "Increasing the capacity of boilers would reduce the first cost of the installation, and consequently less interest would have to be paid on a smaller investment. Increasing the efficiency would reduce the coal bill. Under such conditions power could be produced much more cheaply than at present." The real fact to consider, however, is: That the plant has a certain producing capacity. If this capacity is tapped, the earning power of that given investment is increased. If that capacity is not utilized to approximately its full limit, there is a daily and yearly loss. This affects the standing of the company, the value of its stock, the further manifestation of enterprise, and finally reacts upon the general public unfavorably.

How to Increase Boiler Capacity. — The secret of this method, is to force as much greater weight of gas over the heating surface of the boiler as the capacity is to be increased. If the capacity is to be doubled, twice the weight of gas must be forced over the heating surface. If the capacity is to be increased three-fold, three times the weight of gas must be forced over the heating surface of the boiler. The gases must be forced over with heavy draft appliances, to make the method successful. A fan-power sufficiently great must be employed, for the reason that the power required to push the gas through varies as the cube of the capacity of the boiler as shown in the table given opposite.

TABLE

Power required in the way of forced draft to push the gases through boiler

Capacity of boiler 1	$= 2^3 = 8$
Capacity of boiler 2	$= 3^3 = 27$
Capacity of boiler 3	$= 4^3 = 64$
Capacity of boiler 4	$= 5^3 = 125$

The horse-power required for this purpose is calculated from the volume of gas and the pressure against which the gas is to be moved. In foot pounds this is equal to the product of the pressure in pounds per square foot and the cubic feet of air displaced. The formula appears in the following form:

Horse-power = pressure (pounds per square foot) $\times$ cubic feet of gas displaced per minute $\div$ 33,000, or in another form H. P. = P × G ÷ 33,000 where P = pressure and G = cubic feet of gas displaced per minute. A case in point is one given by a writer, representing a battery of boilers aggregating 1,000 horse-power and the equivalent evaporation is 9 pounds of water per pound of dry coal of average quality. It takes 15 pounds of air to burn 1 pound of dry coal:

Weight of coal burned per minute = 1,000 × 34.5 ÷ 9 × 60 = 63.9 pounds.

Weight of air used per minute = 63.9 × 15 = 958.5 pounds.

Volume of air per minute = 958.5 × 13 = 12,460 cubic feet.

Ordinarily the pressure drop from ash pit to uptake seldom exceeds 0.75 inch of water, but for convenience let the pressure drop in this case be taken as 1 inch.

One inch of water = 62 ÷ 12 = 5.16 pounds per square foot.

Horse-power = 12,460 × 5.16 ÷ 33,000 = 1.95.

Now, according to the cube law, if the capacity of this battery is to be quadrupled, the power needed to move the gases would be 4^3 or 4 × 4 × 4 = 64 times 1.95 horse-power, which equals 125 horse-power. Surely in a unit of this size one engine brake horse-power ought to be produced with one boiler horse-power, and fans having an efficiency of 75 per cent. can be built. With such outfits the consumption of steam for the quadruple capacity would then be: 125 ÷ 4,000 × .75 = 4.2 per cent. of the total steam generated. When one considers that in big power stations power is produced in large electrical units at about half the steam consumption assumed above, and also remember that the fans could be driven electrically, the quadruple capacity appears commercially very feasible — especially if by proper arrangement of the heating surfaces the efficiency of the boilers is increased.

If one considers the sizes of fans usually seen in power plants at present, he may perhaps make the objection that if the capacity of boilers were quadrupled the fans would be so large that they might take up the space saved by making the boilers do more work. There is, however, no substantial reason for fearing such conditions. The fans used at present are unduly large because of their low efficiency; in different constructions the efficiency ranges down from 80 to 10 per cent., and in most is perhaps much closer to 10 than to 80 per cent. Fast running fans of large capacity and high efficiency are now being put on the market. Such fans could easily be placed under or above the boiler they were to serve without being conspicuous on account of their size. The facts thus given are sufficient to show the practical, economical and simple way in which boiler capacities are readily increased. There are a great many central stations where boilers have been purchased that were not necessary. By this method capacity is increased cheaply and satisfactorily.

Objections and Difficulties. — It is claimed that when boilers are forced, the steam is wetter than when it is allowed to take the course of nature. The investigators of this system of developing a higher capacity in boilers claim otherwise. They say, "Another objection that can be made to forcing steam boilers to high capacity is the alleged higher moisture in the steam. Here again one can refer to locomotive and torpedo-boat boilers; these types of boilers are working at about three times the rate customary in stationary boilers and work under conditions favorable to priming; still there is no particular trouble from moisture in the steam. At large steam-turbine plants where steam is highly superheated complaints of higher moisture in steam are not heard. In designing a steam-generating apparatus to produce steam at high rates, probably the greatest difficulties will be met in the furnace.

"To produce four times the weight of hot gas, four times the weight of coal must be burned in the same time. To burn coal thus rapidly without large losses through incomplete combustion of gases and tar vapors driven off from the soft coals upon heating the losses in sparks — losses which always accompany the high capacity of the locomotive and torpedo-boat boiler — the furnace would have to be the larger part of the steaming apparatus.

"To prevent the escape of unburned gases and tar vapors, the principle of slow heating should be used in stoking the coal, in order to avoid the distillation of heavy hydrocarbons which are difficult to burn. Combustion space should be provided in which to burn the lighter and more quickly burning compounds. In the locomotive and torpedo-boat boiler the grates are comparatively small, so that in order to force a large quantity of gases through the fuel bed the velocity of the gases must be high. This high velocity lifts small particles of burning coal from the fuel-bed and carries them through the boiler. To avoid the loss from sparks in stationary boilers, the velocity of the gases through the fuel-bed should be kept so low as not to start the sparks on their way to the stack. This end can be attained by increasing the grate area. The increase in the grate area will also reduce the resistance to the flow of the gases through the fuel-bed. The velocity through the boiler itself, should be high, so as to carry through the boiler any solid particles that might settle on the heating furnace. If the gases flow faster through the boiler than through the fuel-bed, it is obvious that any solid substance that has been light enough to be lifted from the fuel-bed will surely be carried through the boiler by the higher velocity. The work of H. G. Stott and W. S. Finlay, Jr., shows a good method of increasing the grate area. To burn four times the weight of coal on double the grate area would require much less pressure drop through the fuel-bed than if it had to be done on the present small grates. Increasing the grate area would reduce the fan work considerably.

"From the foregoing discussions, it can be seen that the obstacles in the way of higher boiler capacities are superficial, and if the great advantage in the reduction of the first cost of a boiler plant is considered, it seems that the high capacity boiler is bound to come in the near future. This reduction in boiler plant will give steam power a greater advantage over gas power in large central stations."

Output and Efficiency in Boilers. — To avoid confusion it is best to define output as distinguished from efficiency. To increase "boiler output" or capacity, it is necessary to send more hot gases through it. This means more fuel burned and the use of a pressure blower to accomplish it. Efficiency on the other hand is increased by making a better use of the heat ordinarily developed. This is done by forcing the hot gases to take a longer path and thus relieving them of more of their heat. The process is called "baffling" a boiler and simply consists of the introduction of partitions which give the gases a longer and more labyrinthine path before they escape outside. Consequently, it must be plain, that to increase "boiler capacity" an increase in the hot gases passing over the water-containing surfaces must be secured. It has also been made plain that the more intimately the hot gas particles and the water heating surfaces meet, the more heat the boiler will absorb. To gain this end the use of flues of small diameter is necessary in lieu of those of larger size as proven by Government tests.

Efficiency, however, is estimated on the basis of the heat absorbed as compared with the heat developed or generated by the combination. For instance, if the heat developed equals 100 and the boiler absorbs 80, the efficiency, is therefore 80 per cent. Messrs. Kreisinger and Ray, in speaking of a test made on a boiler with a front and rear stoker and analyzing the effects of each, make the following illuminating statement which fits in accurately with the above remarks: "To make this statement clear, let a specific example be taken. Suppose the boiler under consideration has a true boiler efficiency of 90 per cent. This means that from the time the hot gases enter the tubes until they leave the heating surface of the boiler, the latter absorbs by connection 90 per cent. of the heat in the gases that is available for absorption. Thus, for instance, if the gases enter the tubes at a temperature of 2,000 Fahr. above that of the steam, the boiler will cool the gases by 2,000 × .90 = 1,800 Fahr., wherefore, the gases will leave the boiler at 200° Fahr. above steam temperature. Or, if the gases are at 1,000° Fahr. when they reach the tubes, the boiler will cool them down to 1,000 — (1,000 × .90) = 100° Fahr. above the temperature of the steam."

A boiler, therefore, is an apparatus for absorbing heat for steam-making purposes. Whatever legitimate means are employed to secure this absorption are means worthy of practical exploitation for commercial purposes. If a great change in construction is necessary, that change must be made. It must not be forgotten, however, that the degree of absorption of heat is a measure of the efficiency of the boiler. Also that the degree to which the boiler is made to absorb heat is a measure of the capacity of the boiler. Thus, capacity really means capacity for heat or increased steam-making power. Efficiency, however, always expresses the relationship between heat absorbed and heat generated.

Gas and Steam Power Competition. — The gas engine, which operates without a boiler or many of the attendant requirements of a steam engine, ran in close competition with it for a while. The reason, of course, was the need of a boiler in one case and the absence of it in the other. Boilers take room, require more real estate, more labor, and add to the investment, depreciation factor, insurance and general cost. A gas engine, as an entity, meets some of these difficulties without any trouble. Its limitations, however, are evident also, and as an engine the steam machine is preferable under ordinary conditions. Messrs. Kreisinger and Ray state the situation in the following words, which embrace a statement from William L. Abbott, chief operating engineer of the Commonwealth Edison Company, of Chicago. "A few years ago, the gas engine apparently threatened to displace the steam engine, and even the steam turbine, wherever mechanically feasible; that is, wherever real estate was cheap. It has not done so, however, and if one seeks the reason why it has not he has only to ponder some figures in a paper by Mr. Wm. L. Abbott of Chicago. Mr. Abbott states that of the total operating revenue received by large central station companies, 50 per cent. goes out for 'fixed charges' consisting of interest or dividends on investment, sinking fund or depreciation, taxes and insurance; 30 per cent. for operating expenses of all kinds whatsoever, and 20 per cent. for general expenses, including salaries of general officers, advertising, rentals, etc. Of the 30 per cent. for operating expenses, 20 per cent. goes for coal; in other words, only 6 per cent. of the company's gross operating income goes for fuel. Mr. Abbott specifically states that the fuel saving attained by a gas engine plant would be more than overcome by the heavier fixed charges on such a plant; especially would this hold if the heavier labor costs in gas engine plants using producers are taken into consideration. Now it is easy to see that a gas engine plant that could save half the coal (an improbable attainment) would save only 3 per cent. of the gross operating revenue, and that the increased labor costs alone might approach the saving, not to consider the added bond interest." The following figures of the cost of installation of steam turbine plants and of producer gas engine plants of large capacities are taken from a chart compiled by Edwin D. Dreyfus:

COST OF INSTALLATION OF STEAM TURBINE AND OF PRODUCER-GAS ENGINE PLANTS

Total plant Installed Kilowatts	Cost of steam per kilowatt Dollars	Cost of producer gas engine plant per kilowatt Dollars
4,000	75	110.00
8,000	65	104.00
12,000	58	102.00
16,000	53	100.00
20,000	49	99.00
24,000	47	98.50
28,000	46	98.30

The cost of labor Dreyfus gives as 19 to 13 per cent. of the total power plant charge in the steam plant, and from 23 to 20 per cent. in the gas producer plant. (See "Prime Movers for Central Stations, Their Economic Relation," a paper read by Edwin D. Dreyfus before the Association of Iron and Steel Electrical Engineers, September 28, 1911.) The above status of the comparison is present day. It has been repeatedly pointed out (by Messrs. Kreisinger and Ray in their bulletin "The Transmission of Heat into Steam Boilers"), that there are bright prospects of getting two or three and perhaps four times the amount of steam from a given boiler-house investment at a higher efficiency than is usual at present. If steam power house builders should put as much extra money into air preheaters, fans, economizers, etc., as the advocates of gas engines desire put into gas installations, the additional equipment would work some surprises; whether the greater investment would be sound commercial economy in most cases cannot be stated.

It is well known that in modern turbine power plants the boiler room is the costly portion; if it be assumed (probably safely for our purpose) that only one-fourth of an electricity supply company's money is in its power houses, and that three-fifths of this latter investment is in the boiler rooms, then to reduce the boiler room investment only one-half would reduce the total bond interest 7.5 per cent., a liberal dividend on the average amount of capital stock — and it must be borne in mind that such companies always will be run for the benefit of stockholders.

Wasted Dividends in Boilers. — Money often goes up in smoke, but some smoke does not represent even an intelligent wasting of money. The boiler plant can make or break a central station. The two points in its handling or design are to secure a greater output from it and perhaps a higher efficiency while so doing. To get a longer path for the hot gases the boiler may be "baffled" that is, the partitioning of the inside forces the hot gases to make a longer circuit before escaping. This has already been considered, but the tests made on a Heine boiler baffled as described by W. L. Abbott and A. Bement, gave a gas path three times as long as in the original condition of the boiler with the standard Heine baffling. This was accomplished by inserting the two partitions employed as follows: the first partition was laid above the eighth row of tubes and the second above the fourteenth row of tubes. The original partition supplied by the Heine company was on the top over the tubes, the other two partitions were inserted, one from each end as described with respect to the tubes, each about four-fifths of the length of the tubes. Thus, the gas was forced to pass to the right over to the left and over to the right again before going out to the stack. The result of the test showed that with the addition of these baffles the ordinary boiler efficiency increased from about 57 to about 67 per cent. That meant that out of a hundredweight of coal burned 10 lbs. more effect was saved. In a thousand tons consumption the saving would be 100 tons. If the coal consumption is heavier the dollars saved are more evident. Also the boiler capacity is increased by such means.

CHAPTER XXIX

INCREASING THE EFFICIENCY OF BOILERS

Capacity and Efficiency. — To avoid confusion, it is necessary to point out the meaning of capacity and efficiency with respect to boilers. What is called a boiler consists of two important parts; the metallic vessel which contains water and steam and absorbs heat, and should be regarded as a heat absorber; and that part of the steam generating apparatus in which the potential energy of the coal is changed into heat, and should be regarded as a heat generator. Capacity, apart from other considerations, is a measure of the rate of steam production. Efficiency, or true boiler efficiency, is the ratio of the heat absorbed by the boiler, to the heat available for the boiler. A greater capacity means a greater utility attached to the device as a whole; but it may be gained in boiler design and operation, without any loss of efficiency; in fact, as some authorities claim, with an actual gain in this respect. To-day, it is well known, that a broad view embraces not only the study of the absorption of heat in the boiler, but a thorough analysis of the combustion of the fuel in the furnace. They are independent problems, to be considered as heat production and heat absorption conditions, a clear comprehension of which will sweep away much of the empiricism existing since the days of James Watt. In Bryan Donkin's book, entitled, "The Practical Physics of the Modern Steam Boiler," it is stated that James Watt obtained nearly as good an evaporation per pound of coal and per square foot of heating surface as is obtained now. The remark is probably true. At any rate about the only decided superiority of the modern steam boilers over older types is in mechanical construction, and for this superiority credit should be given to the designer of machine tools quite as much as to the boiler engineers. The main reason for tardiness in boiler improvement probably lies in the reluctance of educated engineers to do the dirty and disagreeable work involved in boiler tests.

A Century of Investigation. — Nearly a hundred years of practical investigation of boiler and furnace problems has resulted in little advance. Perhaps the main reason why many of the investigations failed to bring about progress was that boiler and furnace were considered a unit and were investigated together. Various combinations of boilers and furnaces have been built and tested without thoughtful planning. Many of the published results of such tests tend to confuse the performance of the boiler and the furnace in such a way that it is difficult, if not impossible, to tell which of the two should be blamed or praised for the poor or good results obtained from the combined apparatus. Evidently many persons have thought that the combined efficiency could be greatly increased by some mysterious manipulation.

The principles governing the combustion of fuel in boiler furnaces and the absorption of heat by boilers have been little understood. The dogmas that the area of grate should have a certain ratio to the area of the heating surface, and that it takes 10 square feet of heating surface to make one boiler horse-power, seemingly had become so thoroughly fixed in the mind that they were hardly ever questioned. It is only within the last decade that a few engineers have broken away from the old rule of thumb methods and have begun to investigate the functions of the boiler and furnace separately. Their studies seem to mark the beginning of advance in steam-generating apparatus. The following facts from authorities on this subject will prove instructive.

Hydraulic Mean Depth. — It has also been shown, both by the results of experiments and by theoretical considerations, that more heat can be abstracted from the same weight of gas if the length of the gas passage is increased or the cross section of the passage is reduced; the second condition must always include the reduction of the "hydraulic mean depth" of the gas stream. Both of these conditions increase the number of contacts the particles of gas make with the dry surface. With any given velocity, lengthening the gas path lengthens the time during which each particle can make contacts with the dry surface; reducing the cross section or the "hydraulic mean depth" reduces the mean distance of each particle of gas from the dry surface of the plate so that the particles of gas can reach the surface in less time, and in the same available length of time make more contacts. Abstracting more heat from the gases means higher boiler efficiency. The length and the cross section of a gas path is really the arrangement of the heating surface with respect to the gas stream, so that one may say that the efficiency of the boiler depends on the arrangement of the heating surface with respect to the flow of gases.

The preceding deductions can be summarized in the following brief statements:

The capacity of a boiler can be increased by forcing a greater weight of gases through the boiler.

The efficiency of a boiler as a heat absorber can be increased by arranging the heating surfaces in such a way that the gas passages are long and of small cross section, so that they have a small "hydraulic mean depth."

Principles of Heat Transmission. — The application of the principles of heat transmission offers an excellent opportunity for economic improvements in the steam boiler as well as in steam-plant design. It seems feasible to increase the capacity of boilers several times; and at the same time, by properly arranging the heating surfaces in the boilers, to raise the efficiency perhaps several per cent. Increasing the capacity of boilers would reduce the first cost of the installation, and consequently less interest would have to be paid on a smaller investment. Increasing the efficiency would reduce the coal bill. Under such conditions power could be produced more much cheaply than it is at present.

Increasing Boiler Capacity. — Considering the high heat conductivity of metals, there is no reason why boilers could not be made to generate steam at three or four times the rate they do at present by simply forcing about three or four times the weight of gases over the heating surface. This may be considered a conservative statement, as much higher rates are possible and have been attained.

It may at first seem that the power required to force such large quantities of gas through the boilers would be so great that the cost of installing and operating the "draft" appliance would offset any gain from the increased capacity of the boiler. However, such is not the case. It is true that the power required to push the gases through the boiler increases as the cube of the capacity the boiler develops, so that to triple the capacity of a boiler the power required to push the gases would have to be increased 3^3, or 27 fold; or, to quadruple the capacity the fan power would have to be 4^3, or 64 times as large as for single capacity. The one feature that makes high capacity possible is the fact that the power really consumed in ordinary cases in pushing the gases through the boiler and furnace is so small that even after it is multiplied by 64 it still remains only a small fraction of that developed in the boiler. Distrust in the possibility of working steam boilers harder rests on past experience. Engineers are accustomed to hear that the steam consumption in mechanical-draft appliances is from 1 to 2 per cent. of the total steam generated by the boilers which are served by the appliances. With such extravagant "draft" productions, of course, large increase of boiler capacity would not be practicable. Thus, suppose that a fan producing "draft" for a boiler battery at ordinary rates of steaming consumes 2 per cent. of the steam generated in the battery. If the capacity is to be quadrupled, the fan would apparently have to do 4^3, or 64 times, as much work as before.

Since 4 times the capacity is developed, the steam consumed would be $\frac{64 \times 2}{4} = 32$ per cent. of the total steam generated at the quadrupled capacity. This, of course, is a considerable percentage, high enough to make any commercial consideration out of question.

Mechanical Draft Outfits. — However, a little more detailed investigation will show that with present mechanical-draft outfits about 90 per cent. of the energy that can be developed from the steam consumed in the fan engine is wasted in the crude inefficient engine, in the still cruder fan and in the long leaky gas or air ducts having many sharp turns; and that only about 10 per cent. is actually expended in pushing the gases through the furnace and boiler. The power actually needed to force the gas through the boiler can be easily figured from the volume of gas to be displaced per minute and the pressure against which the gas must be moved. This power in foot-pounds is equal to the product of the pressure in pounds per square foot and the cubic feet of air displaced; the following expression gives it in horsepower:

Horse-power =

$$\frac{\text{pres. (lbs. per sq. ft.)} \times \text{cu. ft. gas displaced per min.}}{33{,}000}$$

In specific cases the power expended in pushing gases from the ash pit to the base of the stack or to the uptake can be figured as shown in the following illustration:

Assume that in a battery of boilers ordinarily developing 1,000 boiler horse-power the equivalent evaporation is 9 pounds of water per pound of dry coal of average quality, and that it takes 15 pounds of air to burn 1 pound of dry coal; then the figures are:

Weight of coal burned per minute =

$$\frac{1{,}000 \times 34.5}{9 \times 60} = 63.9 \text{ pounds.}$$

Weight of air used per minute = $63.9 \times 15 =$ 958.5 pounds.

Volume of air per minute = $958.5 \times 13 = 12{,}460$ cubic feet.

Ordinarily the pressure drop from ash pit to uptake seldom exceeds 0.75 inch of water, but for convenience let the pressure drop in this case to be taken as 1 inch.

One inch of water =

$$\frac{62}{12} = 5.16 \text{ pounds per square feet.}$$

$$\text{Horse-power} = \frac{12{,}460 \times 5.16}{33{,}000} = 1.95$$

Now, according to the cube law, if the capacity of this battery is to be quadrupled the power needed to move the gases would be 4^3, or 64 times 1.95 which is approximately 125 horse-power.

Surely in a unit of this size one engine brake horse-power ought to be produced with one boiler horse-power, and the fans having an efficiency of 75 per cent. can be built. With such outfits the consumption of steam for the quadruple capacity would then be

$$\frac{125}{4{,}000 \times .75} = 4.2 \text{ per cent.}$$

of the total steam generated.

When one considers that in big power stations power is produced in large electrical units at about half consumption assumed above, and also remembers that the fans could be driven electrically, the quadruple capacity appears commercially very feasible — especially if by proper arrangement of the heating surfaces the efficiency of the boilers is increased.

Size of Fans. — If one considers the sizes of fans usually seen in power plants at present, he may perhaps make the objection that if the capacity of boilers were quadrupled the fans would be so large that they might take up the greater part of the space saved by making the boilers do more work. There is, however, no substantial reason for fearing such conditions. The fans used at present are unduly large because of their low efficiency; in different constructions the efficiency ranges from 80 down to 10 per cent., and in most is perhaps much closer to 10 than to 80 per cent. Fast-running fans of large capacity and high efficiency are now being put on the market. Such fans could be easily placed under or above the boiler they were to serve without being conspicuous on account of their size.

As an example of the feasibility of increased boiler capacity, the reader is referred to United States Geological Survey Bulletin No. 403, wherein are described 21 tests made on a water-tube boiler of the United States torpedo boat *Biddle*. This particular boiler had a total heating surface of 2,776 square feet. It would, therefore, be rated in land practise as a 277.6 horse-power boiler. On some of the tests as much as 915 boiler horse-power were developed — about 3.3 times its rating in land practise — and still higher capacity was possible. A blowing fan forced the air directly into the fire room: the latter was as nearly air-tight as practicable and was kept under pressure. The wheel of the fan was 5 feet in diameter and 14 inches wide. It was placed directly on the fire-room wall and had no casing, but was protected by a wire screen. The blades were curved in the direction opposite to the rotation of the wheel. At the high boiler capacity mentioned the speed of the fan was about 850 revolutions per minute, and the power required was about 15 horse-power.

Fans Good Enough. — The question may be asked: Why are the fans used at present so crude and inefficient? The answer is that the manufacturer had to sell them cheaply in order to sell them at all, and cheapness and good design and efficiency in apparatus do not go together. Really, there was hardly anything to be gained by more refined and efficient mechanical-draft outfits. Suppose that the steam consumption would by refined apparatus be reduced from 2 per cent. to $\frac{1}{2}$ per cent. of the steam generated in the boiler, would any plant manager be willing to pay, say, double the price for the installation of a more efficient mechanical-draft apparatus to save at most $1\frac{1}{2}$ per cent. of the steam?

Another objection that can be made to forcing steam boilers to high capacity is the alleged higher moisture in the steam. Here again one can refer to locomotive and torpedo boat builders; these types of boilers are working at about three times the rate customary in stationary boilers and work under conditions favorable to priming; still there is no particular trouble from moisture in steam. At large steam turbine plants, where steam is highly superheated, complaints of higher moisture in steam are not heard.

In designing a steam-generating apparatus to produce steam at high rates, probably the greatest difficulties will be met in the furnace. To produce four times the weight of hot gas, four times the weight of coal must be burned in the same time. To burn coal thus rapidly without large losses through incomplete combustion of gases and tar vapors, driven off from the soft coals upon heating, and losses in sparks — losses which always accompany the high capacity of the locomotive and torpedo-boat boiler —

the furnace would have to be the larger part of the steaming apparatus.

General Conditions. — To prevent the escape of unburned gases and tar vapors, the principle of slow heating should be used in stoking the coal, in order to avoid the distillation of heavy hydrocarbons which are difficult to burn. Combustion space should be provided in which to burn the lighter and more quickly burning compounds.

In the locomotive and torpedo-boat boiler the grates are comparatively small, so that in order to force a large quantity of gases through the fuel-bed the velocity of the gases must be high. This high velocity lifts small particles of burning coal from the fuel-bed and carries them through the boiler. To avoid the loss from sparks in stationary boilers, the velocity of the gases through the fuel-bed should be kept so low as not to start the sparks on their way to the stack. This end can be attained by increasing the grate area. The increase in the grate area will also reduce the resistance to the flow gases and thereby reduce the power needed to push the gases through the fuel-bed. The velocity through the boiler itself should be high, so as to carry through the boiler any solid particles that might settle on the heating surface. If the gases flow faster through the boiler than through the fuel-bed, it is obvious that any solid substance that has been light enough to be lifted from the fuel-bed will surely be carried through the boiler by the higher velocity. The work of H. G. Stott and W. S. Finlay, Jr., shows a good method of increasing the grate area. To burn four times the weight of coal on double the grate area would require much less pressure drop through the fuel-bed than if it had to be done on the present small grates. Increasing the grate area would reduce the fan work considerably.

From the foregoing discussions it can be seen that the obstacles in the way of higher boiler capacities are superficial, and if the great advantage in the reduction of the first cost of a boiler plant is considered, it seems that the high capacity boiler is bound to come in the near future. This reduction in boiler plant will give steam power a greater advantage over gas power in large central stations.

CHAPTER XXX

BOILER CORROSION IN CENTRAL STATIONS

The Life of a Boiler. — A mechanism wears out either through its own inevitable depreciation, through which its parts fail of themselves, or because foreign bodies, accumulations, deposits, grits, or chemical action affects it. The atmosphere, moisture, dust, sand and changes of temperature wear things even when not in use. The geologists tell us that all mountains are slowly but surely being levelled by erosion; a process which disintegrates the rock and reduces the mass through the aid of water, winter's cold and summer's heat to powder, soil and gravel as well as boulders and large rocks. These being the influences which act on behalf of nature to reduce things to a final condition, it is not strange that heat, contraction and expansion, sediments, waters with foreign matter in solution, and mechanical strains also act on a boiler, a device constantly exposed to them, tending to destroy its usefulness, weaken its parts, reduce its capacity, and shorten its life. For such reasons as these it is obvious, that if the things that affect a boiler's usefulness are not under control and inspection, its life will be short. The feed water must be pure or many defects will result from its impurity. And as every locality has a different kind of water, it is easy to see how boilers in different places are apt to last different periods of time for this very reason.

Report of the Chemist. — The best way to ascertain "what is what," as the saying goes, it to bring a sample of the water to a competent examining chemist and get his report on the same. The tests to which the chemist will expose the water, will familiarize him as well with the exact nature of the minerals it contains. As a direct result of this, he will be in a position to recommend reagents, neutralizers so called, of a cheap and practical nature, the addition of which will have the effect of reducing the activity of the elements acting upon the boiler. The actions and reactions taking place within a boiler are not only chemical but mechanical. The mechanical effects are more or less the consequence of chemical reactions, but the heat applied and the consequent changes that such energy brings about also leave scars of a deeper and deeper character as time passes with the boiler in full use. Chemists cannot recommend panaceas from the most exclusive sources of knowledge that will meet all conditions. As one authority states (Charles L. Hubbard), "The great variety of impurities, and the varying quantities of each found in different localities, make it impossible to give definite solvent or precipitating solutions suitable for general use." The boiler as a whole is an open-hearth steel shell, or collection of tubes of wrought iron exposed to a varying pressure within, and a high temperature at one end with a comparatively low one at the other end. The result of all these forces is to deform the boiler, should any weakness appear. The weakness may be internal or external. It may be due to fire or water as well as to the secondary influences that prey upon the integrity of the boiler as a whole. Within, is the boiler water, with its mineral matter acting either to combine with the iron chemically, or to settle in a sediment in a layer of increasing thickness as the process goes on. One of these effects would be called corrosion, the actual destruction of the shell of the boiler. The other would be called incrustation, a physical or mechanical effect of a less destructive nature. But the former, the corrosion effect, is one that occurs externally to some extent as well. This is the result of such conditions as prevail to a certain extent in nature and reduce things to ruin. External corrosion is caused by weather, moisture, leaks and in some places by the effects of gases.

Corrosion in General. — There are three forms of corrosion: external, internal and general. As previously stated, external corrosion may be caused by the ground, weather or leakage. The leakage from fitted parts, valves, or valve connections, or other joints in the system, directly affecting the boiler, can be remedied by a careful inspection. It is well known that stonework, brickwork, etc., are likely to retain moisture, and rust the part of the boiler in contact with it. The external corrosion of boilers set in brickwork is only too well known, and is obviated by a careful supervision over the parts liable to this process. Although much of this is not immediately destructive, still all outside wear thins and weakens the shell and to a certain degree impairs the boiler, if it is one run at high pressure. When a boiler fails every part succumbs to the strain. The boiler that holds is one that strain does not affect because of faults.

Internal Corrosion. — The internal wear of a boiler due to the water is more varied. It appears as pitting, honey-combing, grooving and a form of corrosion called wasting. The wasting or general corrosion is the result of the chemical action of the feed water. The same is true of pitting. The effect within the boiler called grooving, is due to the combined action of the chemical and mechanical forces of the water. Each of these defects must be considered.

Grooving. — The boiler is a shell of metal. The varying pressure to which it is subjected strains the plates of which it is composed. They are apt to spring and bend to a certain extent. The boiler is supposed to be protected against these changes by stays. But as often happens, the staying is not well done and the boiler shell is distorted. The staying is presumably done to meet the average pressure put upon it. That is to say, it neither holds the shell too rigid, nor does it permit it to be too lax. The braces and rods used for staying are really the measure of the strength of the boiler. When badly stayed, grooving appears along the edges of angle irons or at their point of greatest strength. This grooving appears in the boiler when the expansion is checked. The dangers due to grooving must not be underestimated. Such an effect may often appear as a fine crack or a fracture in the metal. The superficial appearance is not to be trusted. It often extends to a great depth beneath the surface. The feed water possessing only a slight acidity will rapidly develop the effects of this unfortunate condition to a marked degree. The discovery of grooving means a need for new feed water, or at least feed water of a more alkaline nature.

Strength of Boiler Plates. — One authority gives the values required in the various parts of a boiler to make it safe as well as serviceable. He states as follows: "The usual requirements are that the plates shall have a tensile strength of not less than 55,000, nor more than 60,000 pounds per square inch of section, with not less than 56 per cent. of ductility as indicated by contraction of area at point of fracture; and an elongation of 25 per cent. in a length of 8 inches. The heads are made of 'flange' steel, which is an extra quality of open-hearth steel, made with special reference to toughness and ductility. The breaking load for mold steel tension may be taken as 55,000 pounds per square inch, while the resistance to crushing in riveted joints is about 95,000 pounds. Wrought iron plates are rarely used except when especially called for. They are more ductile and require less care in working than steel, but otherwise have no advantages over steel plates, which are more easily obtained and stronger. The ultimate strength of wrought iron may be taken as

45,000 pounds per square inch for tension and 75,000 pounds per square inch for compression. Rivets are made of iron or steel of a quality and strength similar to that used for the plates. Rivets are subjected to a shearing stress in addition to tension and compression. The ultimate resistance to shearing may be taken as 44,000 pounds for steel and 38,000 pounds for wrought iron. All stays and fastenings which require welding should be of the best quality of wrought iron. Where welding is not necessary mild steel may be used instead. Manhole frames and covers are usually made of cast iron or steel, although wrought iron and mild steel are often used for this purpose. The finer grades of cast iron commonly known as 'gun iron' have a tensile strength varying from 20,000 to 25,000 pounds; the resistance to crushing is about three times as great for small blocks, while somewhat less for larger pieces. In designing the different parts of any structure, a certain allowance in strength must be made to overcome any flaw which may be present in the material. and to offset any sudden load which may be thrown upon the structure when in use. This allowance is called a *factor of safety* and varies according to the material used and the kind of load to be supported. A factor of safety of 6 is recommended for tubular boilers in general use, although 5 is considered safe for thoroughly constructed boilers of good design." The points covered are of interest because they indicate the care employed to arrive at a good result. The fact that the efficiency calculated and the degree of protection expected are not fulfilled when such defects appear as cited, is only too often the case. When boilers are in operation day and night the effect is exaggerated.

Pitting and Honey-combing of Plates. — Pitting is a force of deterioration which occurs in small areas or patches representing scars of from $\frac{1}{2}$ to 10 or 12 inches in diameter. They may have a regular or irregular shape and can be easily recognized. They are an excellent proof of the corrosive action of boiling water containing a dissolvent. When a collection of small pittings are together they are called collectively "honey-combing." The theory given to account for the pitting and honey-combing is that the iron varies in quality. The structure is not the same all over, consequently the wear is not the same under equal conditions at all places. Feed water contains a variety of impurities, some greater than others according to the locality. The carbonates and sulphates of lime and magnesia are common. The fact that water from some localities contains an unusual quantity of chloride of magnesia is supported by tests. But the salts of iron, sulphuric and carbonic acids, and certain other substances of an organic character are also discovered to a degree. It is a well-known fact that water is "sweet" because it contains carbonic acid gas. Water without this gas tastes "flat." That is one reason why the taste of boiled water is different from fresh. Boiling drives out this acid gas. The greater the heat, the more certain it is, that the carbonates will be released and fall as a sediment to the bottom. And as the boiling to which they are exposed goes on, the sediment becomes more and more insoluble. If water is used of a brackish character, it contains chloride of magnesia. The effect of heat upon this is to form magnesia and hydrochloric acid (muriatic), which attacks iron or steel plates very vigorously. On steel plates made under conditions that lead to the supposition that the metal is not uniformly mixed, there is a reason for finding soft and hard patches, but only a reason. Another reason might be the possibilities of galvanic action. This might be due to the ordinary voltaic battery effect, there being two elements, or one of two different qualities acted upon by a slightly acid solution; or there may be a thermo-electric effect. This is very possible, for it is well known that when a metal body is heated more at one point than another a current will flow. Should the path of one of these straying but numerous currents be through the water it is not very difficult to account for some electrolytic action. It is very likely that many conditions arise under the influence of unequal heating, high temperature, and a chemically affected solution, which may be productive of just such effects as pitting and honey-combing. At present we have only hypotheses to offer instead of theories based upon facts.

Incrustation and its Prevention. — Precipitation and evaporation are the causes of sediment. Incrustation is simply the result of a series of layers of sediment. This sediment grows harder and harder, forming what is called scale. The need for pure feed water is shown in the results of impure water upon the boiler surface inside. Water in this respect acts curiously. Whereas some has plenty of foreign matter in solution, other waters with less soluble material form more scale. The consequence is, that the conclusion may be drawn, that it is not so much the quantity of the matter which causes the trouble, as the character of it. For instance, one gallon of feed water holds from 20 to 40 grains of foreign material in solution or free per gallon. But this does not mean that all of the matter thus held will be retained through evaporation. A gallon of water is equal to 8.3 pounds. On the basis of 30 pounds of water per horse-power hour, it is evident that it takes $30 \div 8.3 = 3.6$ gallons of water per horse-power hour. As every gallon holds from 20 to 40 grains of foreign matter, it is evident that every horse-power hour means the possibility of from 72 to 144 grains being left behind. On this basis, it is easy to calculate, that with every 111 horse-power hours, one pound of foreign matter may be left. Should the foreign matter be 40 grains per gallon or 144 grains per horse-power, then the figures show that one pound of foreign matter may be left behind for every 55 horse-power hour of work given out. It is easy to see what would happen with a ten-thousand horse-power plant. Every thousand horse-power hours, would mean from 9 to 18 pounds of foreign matter. According to this, a ten-thousand horse-power plant would mean the evaporation of water that might leave, unless prevented, ten times this amount, or from 90 to 180 pounds of foreign matter per hour. This is all on the basis given, of from 20 to 40 grains per gallon, and an allowance of 8.3 gallons per horse-power hour. By making a very moderate allowance, it is abvious that at least 100 pounds of foreign matter per hour could be left behind, or in a day of 12 hours full load, about 1,200 pounds. Central stations of large size are therefore up against the proposition of having from one-half to a ton of filth left in the boilers each day, causing scale, sediment and corrosion. There are three ways of preventing this: One is to get at the foreign matter before the water enters the boiler, by precipitating it. A second way is to remove the sediment before it becomes hardened. A third way, is to get into the boiler and have the scale chipped off, the sediment removed, and the interior otherwise cleansed.

Purification of Feed Water Physically and Chemically. — One way of purifying the feed water is physical. It is simply passed into an open heater or purifier before reaching the boiler. The method is one combining the use of heat and trays. The trays are open, and the water flows over them, being heated while doing so by means of steam. The heat has the effect of driving the gas out. The carbonic acid gas is the cause of the formation of the insoluble compounds, whose presence is so deleterious to the boiler. A certain number of carbonates are formed anyhow and these are precipitated in the trays and may be removed from them. A coke filter may be placed at the bottom of the heating chamber which holds the water. A great many impurities rise to the surface.. These may be removed from time to time by being blown off. As the trays are readily removable, and the filtering material likewise, it is evident that this system of having settling tanks and heating the water for the purposes described is one of practical importance. The trays are readily cleaned out. The filtering material may be replaced by fresh stuff when affected without difficulty. Getting rid of the carbonates and the carbonic acid gas in this manner means a great saving in the end. The boilers are at least given a chance to remain clean and will not scale if the system is well attended to every day. The sulphates could be precipitated also, but the use of a higher temperature is necessary. As at least 50 pounds pressure would be required, it is evident that the gain is not all that might be expected. The saving to the boilers must not be lost by too great an expense in preparing the water for them. It must be an actual gain in all.

Chemical Purification. — When chemical elements are added to the feed water such as soda-ash, the lime and the soda are affected. This is true of water containing sulphate of lime. In such as this, the addition of the soda-ash, changes the acids of which they are in part composed into soda sulphate and carbonate of lime. The sulphate is easily soluble and passes out. The carbonate of lime is precipitated and leaves easily. The whole trick is in knowing what the water contains and then having a chemist, a water doctor, prescribe for it. For instance, if there is sulphuric acid in a free state and salts of iron, then a prescription of soda-ash and lime is the right thing. If the water contains chloride of magnesia, then soda-ash is needed. This is because the magnesia chloride when heated produces hydrochloric acid. To neutralize this an alkali is required. There is therefore the process of precipitation, filtering and the chemical neutralization of the active acids it contains. Water softening or neutralizing plants are therefore the proper additions to central stations for reasons pertaining to the boiler. Unless this is done, tons of filth, chemical matter and organic decay will settle in the boiler in the course of each month. Corrosion would then go on unchecked and the boiler section of the equipment be completely ruined. The remedy is to purify the feed water thoroughly.

CHAPTER XXXI

BOILER FURNACES FOR CENTRAL STATIONS

Function of the Boiler Furnace. — The boiler holds the water, to which heat is imparted, and in which it is successfully stored until ready to make steam. Even after steam has been made, the temperature of the water will not rise, showing that the storage of heat still continues. Steam formed in the presence of water under conditions where its temperature does not increase is called saturated steam. But when the water has evaporated, additional heat absorbed by it, raises its temperature, producing what is called superheated steam. The current of energy transmitted therefore is the heat. This heat passes into the water as water passes into a sponge. When the sponge can hold no more, it gives physical signs of its saturation. In the same manner, when the pressure over the water permits, the water shows its excess of heat by forming steam. Thus steam means hot water, and hot water means heat applied. The boiler furnace is the source of this heat, and determines the efficiency of the system in many ways.

The furnace may be so built that it represents three conditions in service: First, it may produce too much heat. Second, it may produce too little heat. Third, it may produce the amount of heat required. Too little heat means not enough steam. By this is also meant too low a pressure for work and efficiency. Too large a furnace means too much heat. This means too much steam, too high a pressure and wasted fuel. There can be no efficiency in this case. Calculations and experience must adjust the two items. The coal consumed in the furnace, the heat produced, the heat absorbed by the water and the steam resulting therefrom, with the regular equivalent in mechanical and electrical power, must represent a chain of harmonious links. At one end the heat, at the other end the power, comprises the problem. The engineer is supposed to build a furnace that will develop all the heat the coal is capable of producing. He is then supposed to transform this heat effectively into commercial power, by means of the boiler, engine, and generator. To him the question is this: "For one ton of coal burned at one end, what power is mine at the other?"

This is where the furnace design counts. The furnace consumes the coal, mixing it with the oxygen of the air as rapidly as the drafts permit. The oxygen and carbon unite, producing by chemical change the heat sought. The heat is there to be used, and the question then presents itself of transmitting this heat by radiation and conduction into the boiler. Consequently it is best to know the requirements of a good furnace, one well designed and capable of doing justice to both the fuel and the boiler.

Requirements of a Good Furnace. — The technical features of a good furnace are included under the following heads: First, the capacity must be sufficient. Second, the grates must be properly designed. Third, the design must permit of the proper combustion of gases. Fourth, the design must be suited to the character of the fuel to be burned and the boiler. Fifth, loss of heat by radiation avoided. These considerations may be reviewed separately, for the purpose of discovering exactly what elements co-operate to produce a furnace that will be an effective heat-producer.

1. *Capacity.* — The correct capacity is based upon the amount of heat necessary to produce the steam power. This is determined by the relationship between heat units and pounds of coal. The pounds of coal determine the extent of the grate surface necessary. The grate surface governs the space for combustion. Therefore the chain of reason possesses the following links: Amount of steam required to produce the power governs the amount of water. The pounds of water require a certain amount of heat. This heat can be produced by a given amount of coal burned per hour. This calls for a certain grate surface, a certain space and quantity of air.

2. *Grate Design.* — The area necessary for the amount of coal to be burned is the first essential. Then the grate should be so constructed that ashes and clinkers can be removed with ease and readiness. To accomplish these things the grate must be durable to stand the wear and the heat. There are

many kinds of grates in use, among them are the plain or stationary, the shaking, the dumping, the rocking and the hollow-blast grate. Each has a separate function to perform, to aid in the correct and efficient operation of the furnace.

3. *The Combustion of Gases.* — The gases evolved by the heated coal bed are partly the result of volatilization and combustion. The products of combustion are practically dead, inert gases, but extremely hot. The boiler surfaces are supposed to relieve them of their heat. But the gases that represent the result of volatilization can still be burned and made to evolve heat. To accomplish this before they reach the somewhat cooler surfaces of the tubes and boiler shell is one of the problems in furnace design. The gases thus represent two features as a basis of economic furnace construction. One is that of securing all the heat from the inert gases before they pass out. The other is that of completely burning the combustible gases before they are cooled by contact further on. These proportions are vitally important in good design.

4. *Construction of Furnace to Suit Fuel.* — The kind of fuel consumed determines the shape and size of the furnace. The type of boiler also governs this as well. For instance, if anthracite coal is burned, the grates are placed about 24 inches from the boiler shell. On the other hand, if bituminous coal is used a greater distance is necessary. This is from 30 to 36 inches for the usual run of coal, but even greater, according to the amount of oleaginous matter

and gas-producing power. The ash pit must be large enough to let the air in evenly and amply. In case the fuel is smoke-producing, the air must be admitted for a time above the fire until better combustion prevails after fresh coal has been put on. Consequently sufficient air and distance are items to be duly considered.

5. *Preventing Loss of Heat by Radiation.* — The efficiency of the furnace means the ratio between the heat transmitted to the boiler and that produced by the coal when completely burned. Heat is really radiation in all cases. The chemical action produces ether waves of a certain length which are directed into the vessel or object to be heated. In a furnace, insulating bodies are used to prevent the heat from being wasted by finding a way outside. Brick walls accomplish this in practise preferably made thick or hollow. The radiant heat is thus held within with but one mode of exit. Unless special attention is paid to this feature, the heat energy may either pass outside or if not properly transmitted to the boiler shell or tubes, pass up the chimney.

Types of Furnaces. — There have been invented, several types of stokers, to reduce the labor of taking care of the furnace. By means of such improvement one man is able to take care of more than one furnace without much labor. The average furnace is constructed so as to adapt the various types of grates and stokers to their use. But furnaces of special construction have been designed to get rid of smoke and completely consume the gases of volatilization as indicated by the types described.

The Hawley Down Draft Furnace. — In this furnace two grates are employed situated one above the other. The upper grate receives the coal shovelled in the furnace. As it burns, however, it falls through to the lower grate where the combustion is carried on to the end. The lower grate is horizontal in position, the upper grate being inclined away from it at an angle of about 10 to 15 degrees. The lower part of the furnace of which the lower grate forms part is built of brick or fireproof material to form an arc of 60 degrees. When the fire door communicating with the upper grate is opened the draft passes in downward through the upper grate. It sweeps down into and over the bed of coal on the lower grate. Air is also admitted below the lower grate, so that the two currents of air meet between the two grates, thus insuring a complete oxidation of the combustible gases. As the upper grate is composed of water tubes forming part of the circulating system of the boiler little heat in this respect is lost. The inventor claimed by this arrangement of a water tube grate over a regular grate, the advantage of little smoke, better combustion of the gases and a higher heat efficiency in comparison with other methods.

The Walker Soft Coal Furnace. — This furnace burns soft coal by using a two-part grate. This two-part grate consists of two sections, a forward part, which is lightly tilted up and is stationary, and a rear part, which dumps the ash into the pit. A fire-brick arch is built about on a line with the junction of the two grates. It is built from the roof of the furnace and has a vertical wall above it. When coal is placed upon the front grate and the gases volatilized it is pushed over to the back grate. The ash-pit permits air to pass through the bottom of the grates to the two masses of fuel. It is also admitted through the front wall over the furnace door. The arch with its vertical wall meets the mixture of gas and air, deflects it downward and backward upon the incandescent mass of coke on the rear movable grate. It is evident, that by this process, the smoke is consumed by a more complete system of combustion due to the specially directed current of air, the deflecting wall and arch, and the incandescent contents of the rear grate. In this respect, the principle followed in both the Hawley and this is identical, insofar as an effort is made with two grates and a current of air to more completely consume the unburned gases. In the Hawley there is the tubular grate. In the Walker is found the arch and deflecting wall.

The Wing-Wall Furnace. — The name "wing-wall" implies what it really is. Two vertical walls are built so that they nearly meet, like a pair of wings, back of the bridge wall and near the end of the boiler. Over the combustion chamber a fire-brick arch is built, also a series of what appears to be short walls, abutting against the bridge wall. Thus, there is found the furnace at one end, a set of short parallel walls or piers abutting the bridge wall with spaces between, then beyond this, two walls or wings projecting from the sides and about one-third of the width apart. Between the wings and bridge wall of the furnace an arch is built overhead. Coal is burnt on one-half of the grate at a time, the other half holding hot embers. When fresh coal is placed on one-half of the grate distillation begins. The gases and the hot air from each side of the grate, respectively, thoroughly meet and mix in passing between the wing-walls beyond the combustion chamber. Here the combustion becomes complete. Thus two things are accomplished, the volatilized products of the coal are burned and the heat given out, and the carbon of the smoke is consumed by a more complete oxidization. The fire-brick piers abutting the bridge wall become absorbers of heat and facilitate the process as well as adding heat to such gases as may cool in transit. The cooling of the gases is most apt to occur when fresh coal is added to one-half of the grate.

Conclusions to be Drawn from Furnace Types. — The objective point in furnace construction is attained best in that furnace which consumes all coal, burns all combustible gases, and produces the least smoke. The furnaces which are devised to accomplish this attain success at least as furnaces. The next point must be the success in transmitting this heat to the boiler above. Increasing the length of the path taken by the hot gases through the boiler accomplishes this. The process followed out is called "baffling." By its means, the efficiency and capacity of the boiler is increased. The burning of the coal on the grate or grates, the oxidizing of the gases, and the abstraction of their heat by the boiler sums up the problem. Human ingenuity has been fully tested in trying to obtain maximum results. By developing the grate and stoker, the feeding and combustion of coal has been greatly facilitated. The conditions of design governing the grate and stoker for a working, efficient and practical furnace have been deduced from experiment and theory.

The Design of Grates. — A grate must permit of easy handling. It must be easily fired and cleaned. Hand-fired grates must not be over 6 feet long. If their width is over 4 feet two firing doors are required. Grates are generally inclined toward the rear of the furnace from $\frac{3}{4}$ to 1 inch per foot. This aids very materially in the firing. The grate bars are designed to suit the fuel. They are spaced as low as $\frac{1}{4}$ inch apart or less, and as high as 1 inch. With fine anthracite coal, pea or buckwheat, the spaces are fine, but the air must freely enter. At least 30 to 50 per cent. of the total area must be free. For large sized bituminous or coking coal large spaces are required. But the choice in design is governed by the character and size of the fuel and the extent of the draft.

Kinds of Grates. — There are various kinds of grates such as the plain or stationary, the shaking grate, and the rocking and dumping grate. Of plain or stationary grates there are two kinds. One is made up of sections of from one to three bars not over 3 feet in length, the bars thicker at the top than the bottom; the other, the herring-bone grate bar, is in common use in furnaces for burning "egg" size anthracite. For coals high in ash, which form clinker, shaking or rocking grates are necessary. By their means the chamber can be broken up and the ash dropped without opening the furnace doors. The shaking or rocking grate has three variations of construction: one is the shaking and rocking grate proper; the second, is the dumping type of grate; the third, is the combined shaking and dumping type of grate. The mechanism to operate the grates for shaking or dumping or both are quite distinct. One shaker generally operates one set of bars and another shaker the other. To break clinker they are used alternately.

The Dumping Grate. — The sections of a dumping grate are made rather large. When the clinker has formed and binds the sections, the particular section to which it is attached is rocked back and forth from a horizontal to a vertical position. The clinker breaks and falls through the ash-pit. This particular function may be all this grate performs. The other operations have to be done by hand by means of the utensils employed.

The Rocking and Dumping Grate. — This type of grate does several things. Its rocking motion is effective in breaking up soft coal that cakes. It is also a grate that permits the ashes to sift through from an anthracite coal fire provided little clinker has formed. When the levers operating this grate are fully moved, each right angular unit swings through 120 degrees on its shaft. This is called the cutoff movement and has the effect of breaking up the large clinkers and dropping them into the pit below. The grates compose two parts, capable of independent operation when so used.

The Hollow Blast Rocking Grate. — This natural draft grate is set in with a supply duct to carry it air. The air comes from a pipe in the bridge wall. This pipe supplies air to a set of hollow trunnions on which each line of grate is built. It passes through the air passages on which the grate units are built, up in fine streams through the interstices at the top of the bars. The air is pumped through and thus supplies a bed to the fuel on the grate. By this system low grate fuel is consumed, and refuse. The gases of volatilization are thoroughly mixed by this system and give off a greater amount of heat than by allowing the air to enter in the regular manner.

Losses by Shaking Grates. — The choice presented to the engineer is that of losing from 1 to 3 per cent. of the coal through the use of a shaking grate, or having a better combustion of the resulting fuel and the necessary elimination of clinker and ash. As the saying is, "Every rose has its thorns," and the contemplation of the "grate" subject shows that this epigram is true. All grates that do things the hands may do better, are apt to produce unintelligent results. The gain in heat must always offset the loss in fuel. This is true in the majority of the efforts made to improve the furnace by keeping the fire door closed as much as possible.

Mechanical Stokers. — The fireman's job is one that calls for constant attention to the fire. The opening and closing of the furnace door permits heat to escape. The coal must be distributed in a certain way to obtain the best returns from the fuel. All of this takes time, labor and skill. The stoker is a device by means of which coal and air are automatically fed to the furnace. The advantages are as follows: One man can readily take care of more than one furnace. The firing being done automatically it is more even and therefore better. Through this condition, the combustion is uniform and more efficient. Finally, the furnace doors being closed help to save the heat energy. The feeding of coal and air together act as a means of producing a nearly complete smoke combustion. There are two kinds of mechanical stokers on the market: First, the "overfed"; second, the "underfed." The objection that seems to exist against them is not strictly economic but proceeds from the owners of small plants. The first cost is considered heavy, but in large plants, the certainty of effect gained by them and the reduced cost of firing, have been the means of their permanent introduction. Tests have shown an increased efficiency, which, added to the other advantages, is quite sufficient to establish them in central stations.

Overfed Stokers. — In "overfed" stokers, the fuel is fed into a hopper, pushed from it over a "dead plate" as in the "Roney" and thus onto the grates, which are built into a series of sloping steps down to a dumping grate next to the bridge wall. A small steam engine operates the rocker bar, which gives the grate bars a backward and forward motion. The "pusher," pushing the fuel down, controls the rate of feed. The length of the stroke and the number of them per minute control the fuel supply to the fire. Ashes and cinders deposit themselves through the dumping grate to the ash-pit.

The Acme and Wilkinson stokers do about the same thing. Both have inclined grates, movable bars giving a forward motion to the coal fed from a forward hopper. But in this stoker, hollow grate bars, through which air is forced by steam, supply a novel and useful feature. The Duluth stoker is a separate mechanism which can be wheeled out. Its bars compose a continuous chain running over sheaves at the rear and sprockets in front of the furnace. A hopper in front, feeds the coal by means of an adjustable plate, which permits of the proper thickness or bed of coal on the grates. In addition to these operating on about the same principle are the "Babcock and Wilcox," the "Playford Chain Grate Stoker," the "Coxe Automatic" and the "Green Travelling Link Stoker."

Underfed Stokers. — The "American" and the "Jones" stokers are of the underfed type. The coal in this design is fed from beneath. In the "American" a screw conveyor or worm, operating in the conveyor or pipe, connecting to and through the coal magazine forces the coal forward and up over the grates. Air pressure due to a forced draft is used in this device. The hopper feeds into the magazine from which the coal is extracted by the screw. In the "Jones" type a plunger is used operated by a steam piston. A forced draft is required by this as well. Another similar device is the "Taylor," differing in no essential principle from these. The furnace is thus rendered more efficient a heat producer by improved grates, uniform feeding and automatic stoking. In central stations every per cent. saved at this end can be rendered into dollars and cents instead of escaping up the chimney as waste heat.

CHAPTER XXXII

ELECTRICAL INJURIES

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The usual injuries encountered in the industrial applications of electricity are due to exposure to flashes and to actual contact.

Symptoms of Flashed Eyes. — Eyes which have been exposed to electrical flashes become very red, due to the sudden dilatation and congestion of the blood vessels of the mucous membrane lining the lids and in part covering the eyeball, known as the conjunctiva; such an inflammation of it constituting a conjunctivitis. The pain is intense, there is an aversion to light, and a copious secretion of tears.

Often the eyelashes and eyebrows are singed, and charred hair, skin débris and dust particles may fill the eyes, contributing to the severity of the above symptoms.

In the more severe cases, in addition to the conjunctivitis, there may appear around the central transparent area of the eyeball, known as the cornea, a zone of red; such a zone of red in the white of the eye, near its junction with the colored part of the eye, known as the iris, constitutes an iritis. It is characteristic of a congestion of the blood vessels within this portion of the eyeball. If the heat of the flash is sufficient, as in the more severe cases, the superficial layers of the transparent cornea are coagulated.

Treatment of Flashed Eyes. — The immediate treatment consists in washing the region of the eye and the eyelids with eye-water,[1] then washing the eye itself. Upon dropping into the eyes a sufficient quantity of three per cent. cocaine hydrochloride solution, the débris may be mopped out with clean cotton wrapped on a tooth pick. The coagulated tissue of the cornea is similarly mopped off.

The immediate relief of pain is secured by cold compresses over the eye, and the chief remedy in the subsequent treatment is cold compresses; merely cotton or a clean cloth laid on ice, or made wet in ice water, and changed by the patient every two minutes. The cold compresses serve to contract the dilated blood vessels, and thus control the painful congestion. They can be employed for an hour at a time, as the patient lies down; not constantly, but every other hour. This enables the patient to get some sleep, for flashed eyes are most painful when he is relaxed and ready to sleep. Eye-water is used

[1] A serviceable formula for eye-water is as follows:

R	Sodii biboric	0.30
	Acidi boric	0.15
	Alumini sulphatis	0.06
	Zinci sulphatis	0.06
	Aquae camphorae	30.

M.

Sig. Use freely as an eye-wash.

every hour. In severe cases adrenalin hydrochloride, 1:5000 solution, is used every half-hour; atropine sulphate, one per cent. solution, a few drops every four hours to control the iritis referred to above, if this symptom manifests itself. Also it may be necessary to apply castor oil every two hours to prevent the eyelids and eyeballs from growing together (synechial adhesions) if the corneal tissue has been much injured. In the milder flashes the three latter remedies are omitted, as the patient wears smoked glasses and returns to work in two or three days. Recovery is prompt and complete in practically all cases.

It is conceivable that high intensity flashes are capable of seriously affecting the optic nerves in susceptible cases, though such a case has never come under our observation. The fire of the flash that singes the hair or burns the skin is but one element in the production of this type of injuries, as eyes may be "flashed" and present the congestion, lachrymation, pain and aversion to light (the cardinal symptoms of flashed eyes) when the person is too remote from the heat of the flash to be burned. The intense light of the electric welding arc will produce a similar conjunctivitis and iritis; the effect probably being due to the ultraviolet rays present in the electric arc. However, the red and blue glasses worn in the helmets of the welders protect them from the high intensity light.

Symptoms of Flashed Skin. — Flash burns of the skin are usually burns of the second degree. That is to say, while destroying the outer layer of the skin (the epithelium) they do not injure the inner layer of the skin (the corium) nor the deeper tissues. At first these burns may present a mere congestion; the skin is red, as from exposure to the sun, and they have the appearance of a first degree burn, scarce worth while dressing and bandaging. But there is pain, some redness, and by the second day huge blebs or blisters may have formed. Usually the hair is scorched; often the outer skin is blown off, and the surface looks ragged. Under proper treatment of these cases there is seldom any formation of pus, and they will heal up, usually without leaving a scar. We have treated many of such burns with the happiest results. We have treated men whose features were so altered by burns and the eyes so swollen shut, that their own mothers would not have known them. To the unitiated it seemed they were scarred for life, yet within two weeks they were able to resume work, and within two months no trace of their burns was discernible.

Treatment of Flash Burns of the Skin. — The immediate treatment of flash burns consists in securing the highest obtainable degree of surgical cleanliness with ethereal soap[1] applied with numerous

[1] A good formula for ethereal soap that dissolves and removes the dirt and grease, at the same time rendering the area antiseptic consists of:

Sulphuric ether	4 oz.
Turpentine	1 oz.
Alcohol	3 pts.
Surgical soft soap	4 lbs.
Water, enough to make	1 gal.

cotton sponges (using sterilized absorbent cotton such as is sold for medical uses) and the application of sterile gauze dressing, well covered with Unguentine. We find this ointment uniformly reliable; it soothes the pain and promotes recovery. A loose gauze bandage is applied and the part put at rest.

The subsequent treatment consists of daily redressings. When the blebs are large, we scissor them open freely, but allow the outer skin to remain for some days, as it is in itself a splendid protective covering.

These burns must be washed clean, then there is little liability to infection with its pain, the formation of pus, and the resulting long term of disability. But should it become infected and pus form, we at once trim away the skin débris, so as to allow no pockets for the retention of infection. In the absence of infection, that is, when the pus-producing bacteria do not invade the wound, the dead skin is removed within a few days, after the inner sensitive layer of the skin has had a chance to harden somewhat, and to lose its hypersensitiveness. When the healing has progressed we sometimes apply ten per cent. ichthyol in petrolatum, to facilitate the formation of normal skin. After recovery, in most cases, the skin remains red and sensitive for some weeks. We instruct the patient to wear canvas gloves and otherwise protect the new skin from grime and weather, as it is prone to eczema.

The dry, open method of treating such burns, namely, that of powdering on stearate of zinc freely and exposing them unbandaged to the air, is more or less successful in hospital practise, but not adapted to ambulatory patients, especially those that may live on the streets and in dirty houses, and who may return to work before complete recovery.

Symptoms of Flashes from High Voltage. — In contrast to the usual benign burns from low voltage is the severe burning from high voltage flashes, causing destruction of all layers of the skin (third degree burns) over large areas. Great mental excitation, even transient mania, is sometimes observed in these cases: again, on the contrary, some patients are relaxed, unconscious, not breathing, and may require immediate resuscitation by artificial respiration.

Treatment of High Voltage Flashes. — These are hospital cases, and they may require much care to ensure their recovery. Delirium is sometimes encountered. Where large areas are burned there is increased danger from sepsis. When convalescence is established, skin deficiencies are restored by grafting. In such cases the recovery is slow. Scarring will be more or less extensive, depending on the depth and extent of the burns and the infection that may be associated.

Prevention of Electrical Flashes. — Careful attention in handling switches and plugs is imperative. Circuits should be opened whenever practicable during tests and in repair work, and danger signs erected, as well as isolating the test by means of ropes. In repairing of transmission lines and transformers connected thereto, the lines should be thoroughly grounded at the point of repair on any side from which power may accidentally be thrown on. Attention to such details as every electrician knows, but sometimes ignores, will do much to minimize the number of these injuries. With sleeves rolled up to the elbows, no gloves, and the face near a switch when it is opened on a circuit carrying a heavy load, the exposure to flash burns is unnecessarily increased.

Great caution should be observed in approaching live high voltage conductors, and a safe distance maintained. Even the high voltage of switchboards has been known to jump some distance, envelop a man in its flaming discharge, seriously burn him, and violently throw him down. High voltage never should be disregarded under any circumstances. It should be respected.

Causation of Flash Injuries. — Flashes of arcs occur upon breaking or momentarily short-circuiting, direct and alternating current, as, for example, where a switch in a heavily loaded circuit is opened by mistake, where wires with deficient insulation become crossed, or where a workman at a switchboard allows his screw-driver to slip, causing a short circuit. A score of ways there are that will cause a sheet of flame to issue forth, surprising even the experienced, but more often the novitiate.

Although electrical flashes are of but momentary duration, the heat developed is often very great. This great heat will produce painful burns of the unprotected skin and eyes. Similar burns may also result from continued exposure to the rays of the electric arc as is used in welding, though the operator may not have been near enough to feel any intense heat. Such burns usually do not become apparent till several hours after the exposure. Eyes can be flashed by the welding arc at a considerable distance.

Such is the origin of the mild flashes ordinarily observed and readily amenable to treatment; then there are the severe burns from high voltage conductors.

With a voltage much in excess of 15,000 a man seldom makes contact, for the voltage jumps over to his fingers, flexing them, and making it impossible to make contact; 33,000 volts will leap through ordinary insulation and go to the man who approaches it. The discharge is instantaneous and takes place before he can make actual contact with the conductor, unless he is thrown upon it. On this account there is less liability to contact burns from high voltage than from low voltage. This discharge that bridges the interval between the circuit and its victim may cause extensive face burns. Such a flash is but a leakage from the high voltage conductor, and to the extent that it spends its force on the surface, there is diminished liability of serious electrical shock.

The man approaching the high voltage conductor sinks as if shot when the discharge strikes him. Although the conditions may be such that he will receive a heavy current, the discharge may carry with it only a small current, yet enough to flex his arm and leg muscles (the flexors are stronger than the extensors) and cause him to fall all over himself. Such precipitation assists in extricating him from what might be a dangerous contact, whereas in a lower voltage, with hand grasping the conductor, the excessive electrical stimulation of his muscles causes his grip to tighten; his fingers flex tetanically; he is unable to release his hold.

The flashes from high voltage may moreover carry sufficient current to cause a suspension of animation — to be considered later.

Contact Injuries. — The two types of contact injuries are shocks and burns. The passage of an electric current through the human body may cause a momentary unpleasantness, the retention of the victim within the circuit unable to release himself, a suspension of consciousness, during which he falls, but revives again, or a suspension of animation, requiring artificial respiration.

Resuscitation by Artificial Respiration. — The efforts at resuscitation must be begun the instant the patient is freed from the contact. Sixty seconds is too long for preliminaries. The comrade nearest him must know how to give artificial respiration, as loss of time in summoning a physician is unpardonable. The services of the latter are often essential in winning back a life nearly extinguished, but the artificial respiration must be begun early, and perseveringly continued, if the life is to be saved.

While the heart beats there is hope. Artificial respiration helps sustain the cardiac action. Even when no radial pulse is felt, the comrades are not justified in ceasing their efforts at resuscitation, as the heart may still be beating feebly. In those occasional cases, where the heart action has ceased, as the physician upon his arrival may determine with his stethoscope, there will be no possibility of restoring the normal respiration by any method of artificial respiration. Yet the victim should have the benefit of any doubt, for there are few cases of accidental electrocution where the victim cannot be restored from the electrical shock, if appropriate immediate efforts at resuscitation are instituted.

Rules for Artificial Respiration. — The three essentials of the Prone Pressure method[1] of artificial respiration to be remembered and practiced in anticipation of an emergency:

1. The man is laid upon his stomach, face turned to one side, so that the mouth and nose do not touch the ground.

2. The operator kneels, straddling the patient's hips, or kneels by either side of the hips, facing the patient's head.

3. The operator places his spread hands upon the lower ribs of the patient and throws his own body and shoulders forward, so as to bring his weight heavily upon the lower ribs of the patient.

The operator's downward pressure should occupy about three seconds, then his hands are suddenly removed. Squeezing the chest in this manner forces

[1] See Journal American Medical Association, Vol. LI., No. 10; Collier's, Vol. 41, No. 25; The Electric Journal, Vol. VIII, No. 2 and No. 8; The Medical World, July, 1911.

the air out of the lungs. On release of the pressure the elasticity of the chest walls causes them to expand, and the lungs are refilled with fresh air. This act should be repeated an indefinite number of times at the rate of twelve times a minute. In the excitement of the occasion the danger is that the rate will be too rapid. If the operator is alone with the patient he can adjust the rate of giving artificial respiration by his own deep, regular breathing; if more persons are present, a watch can be used to advantage to regulate the rate.

Any evidence of returning animation should encourage the operator to continue his efforts. If often requires one-half hour to two hours. In electrical shock seldom over one-half hour, but in cases of drowning, especially, it is advisable to keep at it, for recoveries are alleged to have resulted after three hours of continuous artificial respiration.

Supplemental Efforts. — If the operator is alone with the patient, the artificial respiration is his chief concern, and offers the only hope for the victim. Yet if others are present they may keep the crowd back, loosen tight neck-bands, if any, and hold a cloth saturated with Aromatic Spirits of Ammonia near the nose. As a respiratory stimulant it is even more useful than oxygen, yet is valuable only as an adjunct to the artificial respiration.

The physician upon his arrival, should the respiratory function continue in abeyance, may render great assistance by the hypodermic administration of Atropin Sulph. gr. 1–100 and Strychnin Sulph.

gr. 1–30, which can be repeated at his discretion, or he can stretch the Sphincter Ani.

Injudicious assistance is often harmful. No liquid should be given by the mouth to an unconscious patient. Under conditions met with in electrical shock, and in those near-drowned, liquids given are more liable to enter the lungs the than stomach.

When the rhythm of the respiration is re-established and consciousness is restored, the patient may experience thirst and may be encouraged to drink a teaspoonful of Aromatic Spirits of Ammonia in one-half glass of water, and the same repeated after a short interval. He may be cold and weak and in that case will require blankets and artificial heat; or he may be strong as ever, in which case it helps wake him up to allow him to walk with assistance a reasonable distance to the physician to have his accompanying burns dressed.

Yet a word of caution is here necessary. When artificial respiration has succeeded and the patient is recovering from the electrical shock, he may be excited and may desire to stand up too soon. He must be dissuaded from doing so until fully out of the shock — his heart and breathing fully restored — before he is permitted to sit up, and finally stand up. He needs watching for some time. If he gets up too soon a second effort at artificial respiration may be unavailing: it may be the collapse of heart failure.

Forethought. — Suspended animation requires instant relief, yet so often many who have been trained to give artificial respiration are helpless in such an emergency. Many are excited, frenzied; all turn white. Some jump up and down, others scream and are incapable of intelligent action. With deliberate, prudent forethought, akin to the German Bureau of Strategy, each individual must study out in advance just what he would do under given circumstances — if home or factory were on fire, or a comrade were on an electric circuit. Every action must be carefully thought out in advance. Testers should know if the floor is a non-conductor, and should know the location of switches that may be opened, or the methods of pulling a man off by his clothing, or otherwise, in such a manner that the rescue is safe. Then he must previously study out and know how to give artificial respiration, so that there will be nothing unforeseen, nothing unanticipated, in an apparent calamity that spreads consternation particularly among those not qualified to meet the responsibilities of the situation.

Advantages of Prone Pressure Method. — We adopted the Prone Pressure method because: 1. It is easy to learn. Any intelligent man can be shown in a few minutes, and can practice on his friends, and they on him, until he becomes an expert in the art of giving artificial respiration. 2. It requires no apparatus. There is no delay due to waiting until an emergency outfit is found. 3. It can be carried on easily by one person. A mere boy of twelve can resuscitate an overweight adult and maintain sufficient inflow and outflow of air (tidal air), as much as he would secure were he able to breathe voluntarily. One operator can work without exhaustion for an unlimited length of time by this method; there is no need of team work, and teams working in relays, as for example with the Sylvester-Laborde method. Hence, there is diminished temptation to quit too soon. 4. Spirometer tests show the Prone Pressure method superior, as exhibited by Prof. E. A. Schafer of Edinburgh before the American Medical Association. 5. It is the method that best meets the complications of suspended animation as encountered in electrical shock: (*a*) In the usual excessive relaxation of electrical shock, there is great liability of swallowing the tongue with the patient on the back, and considerable difficulty in holding it forward; by the prone pressure method, with the man on his stomach, the tongue falls forward of its own weight. (*b*) In the frequent bronchorrhœa (excessive secretion from air-passages) and edema of the lungs (leakage of blood-stained serum into air-vesicles) by laying the man prone on his stomach, these secretions run out of the mouth, and there is no danger of drowning the man in his own secretions. By the older method, where this complication was successfully met, the patient had to be rolled on his stomach occasionally to permit of the escape of bloody mucus, then rolled on his back, and the secretions churned up in his lungs until the artificial respirations are another time interrupted by rolling him on his abdomen to let the secretions escape from his mouth. (*c*) In cases of electrical shock presenting muscular rigidity or continuous rigid contraction of the muscles, tetanic, his arms cannot be manipulated; by pressure on the ribs, according to the prone pressure method, and simultaneous pressure on the abdomen by a second comrade, mucus is expelled from the mouth within a brief period, and with the first forced expiration there comes a general muscular relaxation and continued artificial respiration leads to recovery.

Theories of Electrical Shock. — Physiological experimentation on animals adduces the conclusion that in suspended animation (cessation of respiration and cardiac action) from electrical over-stimulation the brain loses its power to react to stimuli. This irritability (power to react) is only temporarily suspended, so that life, if not entirely extinct, is dependent on artificial respiration until such time as the brain (the central station) recovers its irritability.

Like the dry cell battery of a common door bell, which, if rung too continuously, ceases ringing; so the brain, if over-stimulated to the point of exhaustion, suspends vital operations. The dry cell left to itself recovers, and the bell will ring again; the brain possesses infinitely greater power of recovery. But artificial respiration must be employed to supply oxygen, so that oxygenated blood may help sustain the cardiac function, else there will be no interval of rest allowed the exhausted brain in which to recover.

While the irritability of the brain, which subsides immediately after the shock, will within a few minutes recover, everything depends finally, where artificial respiration is employed, on whether the action of the heart continues or not.

A second theory is that of asphyxiation, or the non-oxygenation of the blood. There is heightened chemical activity from the current that induces the electrical shock and much carbon dioxide is produced.

The excess of carbon dioxide in the blood paralyzes the respiratory center of the medulla. In asphyxia artificial respiration is required, and must be continued until the blood is oxygenated, before the normal respiratory function will be re-established.

A third theory makes electrical shock depend upon a sudden dilatation of the great vessels of the splanchnic area. The blood vessels are held in a state of tonic constriction by nerves of the sympathetic nervous system. The shock is conveyed from the cerebro-spinal nervous system to the sympathetic. This tonic constriction of the splanchnic vessels (those of the abdominal viscera) is suddenly recalled, suppressed, and in a moment these vessels dilate to twice their normal diameter, able to contain four times the quantity of blood normally contained, and the man in shock is liable to die of hemorrhage into his own vessels. Paradoxically, he can die of hemorrhage in this state without shedding a drop of blood.

Respiration will cease at once from anemia of the medulla; the brain depends for its blood tension on the tonicity of the vessels of the splanchnic area. Not only will the brain be without blood, but the heart will have no blood to impel into the arteries, and unless artificial respiration is resorted to instantly the increasing asphyxia will speedily result fatally.

I believe that all three theories are interdependent, and that in addition there may be other factors.

Symptoms of Contact Burns. — The burns from electrical contact are generally of the third degree; that is, there is a destruction of both layers of the skin, and even of the deeper tissues. The real extent is not immediately apparent. The tissues are coagulated, and there is a deep white slough that is slow in separating. At times, fingers are burned to a cinder, or the vascular supply so destroyed as to cause a dry gangrene. These burns are as a rule painless, and upon recovering from the shock the patient may not consider himself burned, but later the discovery is made. In the milder forms they may not report for treatment until some days after the accident, by which time the burn has become infected. But these burns are worse than they look and are obstinate to heal, especially after infection sets in. Ordinarily, in the milder cases, the patient is best treated while continuing at work. In the severer degrees, as above mentioned, they are hospital cases.

Treatment of Contact Burns. — The immediate treatment in case of such burns consists in surgical cleanliness, secured by ethereal soap applied with numerous cotton sponges. For the milder burns, we prefer depletol, or 10 per cent. ichthyol on sterile gauze, to facilitate the separation of the necrosed (dead) tissues. When the slough has separated, we commonly employ balsam of Peru as a dressing, and alternate with thymol iodide at times. When crusts form under this mode of treatment, we employ zinc oxide ointment, to remove them, and continue the daily dressings until the defect has granulated in and the area is covered with healthy skin.

The severer burns in hospital practise are treated by open, dry or wet methods, in accordance with the ideas of the surgeon on the particular service. It is customary to be conservative in waiting for gangrene to demark the necrosed tissues, rather than to resort to immediate amputations, inasmuch as the boundaries of the damaged tissues cannot be immediately determined. Burns of the palms which to the uninitiated may seem trivial, may necessitate the amputation of the hands, due to necrosis of the tendons.

Factors in Causation of Contact Burns. — There is a wide variety of external and individual conditions that influence the extent of electrical injury, and there is an interdependence of circumstances that makes tabulated results and reports of accidents apparently inconsistent. At one time 110 volts are involved, and there is a fatal accident; at another time 15,000 and recovery will ensue.

The voltage being equal, alternating current is probably less dangerous than direct current. With alternating-current frequencies below 50,000 cycles, and equal voltage, more response is produced than in frequencies approaching 100,000 cycles per second.

High frequency currents, even though of high voltage, such for example as are produced by X-ray induction coils, and also that of wireless telegraph apparatus, are not ordinarily dangerous, on account of their tendency to seek the surface of conductors in their circuit, rather than flow by way of internal path.

While burns and electrical shock are often associated, it is noteworthy that in many cases of accidental electrocution, there are no demonstrable burns.

Tabulated figures on the electrical resistance of the human body vary greatly. For example, by the bridge method on the Baker Static Machine the hand-to-hand resistance on various individuals was found to be 40,000 ohms (min.) to 140,000 ohms (max.). Moistening the hands cuts the hand-to-hand resistance to 29,000 ohms, immersing the hands in water reduces it to 5,400 ohms, and making the water conductive by the addition of salt, further reduces it to 4,600 ohms.

While approximately 15 amperes of current are used for criminal electrocutions, with electrodes at base of brain and calves of legs, yet $\frac{1}{10}$ ampere may become dangerous under certain conditions of contact, and $\frac{1}{2}$ ampere is considered prohibitive.

A current that is harmless at first, by breaking down the skin resistance and taking an internal path, may become dangerous.

The location and number of contacts is an important factor, as well as the duration of the contact. "A small current applied over the pneumogastric nerve in the neck would paralyze the heart, whereas taken through the hands or body, the path must be over the nervous mechanism controlling the respiratory and cardiac centers to produce death." But it can be argued the electric current follows the blood vessels, not the nerve trunks; oil is a non-conductor, the nerve trunks are chiefly fat, the saline constituents of the blood make it a good conductor.

Panic (the emotions), causing profound vasomotor paresis and vascular dilatation from slight injury, and subsequent failure in performing artificial respiration, probably accounts for many deaths. A defective heart is also a possible cause of death, where there are fatalities and little current is involved.

It can be contended that electric current does not kill in most of the deaths attributed to it. Some of these deaths are undoubtedly the result of neglect; resuscitation is delayed, improperly conducted, or discontinued too soon. An electrician in our plant within six years in his own department has rescued six from death's door, six out of six, a record of 100 per cent. saved. He is there within three seconds, and begins the artificial respiration in the spot where they fall, and keeps by them in that spot until they have fully recovered. He is enthusiastic for the Prone Pressure method.

This outline sketch of electrical injuries is designed to emphasize the curability of this type of accidents, and to encourage everybody to learn how to give artificial respiration by the Prone Pressure method, with the purpose of minimizing the number of fatalities from electrical shock.

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