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This Central Power Station has sufficient capacity to furnish the wonderful conveniences of electricity for a million homes

ELECTRICITY IN HOUSEHOLD SERVICE

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

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CONTENTS

AN ELABORATELY LIGHTED DINING ROOM

By the control of some four hundred and fifty lamps distributed behind the cased-glass ceiling panel the possible variations which can be secured in lighting intensity, direction, and color are rivaled only on the stage. (See "Electricity in Household Service; Part II, Lighting" by E. J. Edwards, page 162.)

GENERAL ELECTRIC
REVIEW

ELECTRICITY IN THE HOUSEHOLD

Each new convenience placed at our disposal is at first much talked about and highly valued, but its continued use and the arrival of newer objects of interest sooner or later rob it of the attention and appreciation it deserves. At one time, the watch was a possession of which the owner was proud indeed; but today it is simply part of our personal paraphernalia and we consult it without giving conscious thought to the timepiece itself, but only to the object of our interest "the time."

The introduction of such public utility services as city water supply, sewage removal, and gas, electricity and telephone connections have each in turn claimed public interest; and the average householder has progressively found it to his advantage to utilize them for he cannot produce them himself, or cannot produce them as cheaply, for his own individual use. However, as with most of our other every-day possessions, they have become so familiar to us through their constant utilization in daily activities that we have relegated them to the background of our conscious thought and there unfortunately they usually remain disregarded.

Now that the hostilities of the great conflict in Europe have ceased, and after having been "fed up" on things military, industrial, and maritime, we can with relief turn our attention again to our homes—homes that through the victorious efforts of our allies and ourselves have been saved from the devastation of war.

The four leading articles of this issue have been especially prepared to present the various features which electric service affords in the operation of a home. While, by reason of familiarity, the subject may appear commonplace to some of us who follow the electrical profession, it will be distinctly worth our while to pause and read of the results which have been achieved by those who make it their business to brighten the home and minimize the labor of its maintenance.

There is probably no type of establishment which offers a more varied field of application for electric devices than does the household. It can economically and efficiently utilize the energy of central-station service in the form of light, heat, and power and also in the production of "cold." Furthermore, its importance is indicated by the amount of its purchase of electrical appliances and electric service which, while made up of small individual units, aggregates an enormous total.

The average householder would perhaps be astonished to learn that the company which furnishes his electric service, and which to him is represented only by an office and by a few cables in the street, is but one of some 5500 similar organizations the investment in which is rated at three billion dollars. This, however, is probably to be expected when it is considered that most of the consumers never see the generating station, since it is located at some distant point. These stations, in the larger of which is sometimes concentrated sufficient power to operate a fleet of eight of the largest and most powerful battleships afloat, supply some fifty million persons with the benefits of electric service and yet are so efficient that their fuel requirements for this service are supplied by less than four per cent of the total coal consumption of the country.

Electric service was first introduced into the home for the purpose of furnishing an improved illuminant; and, during the years that have followed, experts have placed at our disposal highly efficient incandescent lamps and almost endless varieties of fixtures with which to obtain any desired illumination effect. One of the outstanding problems, however, that remain in the art of applied illumination is the avoidance of glare; and consequently much care must be exercised in the selection of lamps and fixtures to eliminate the cause of this evil.

While the utilization of electricity in the forms of power and heat followed considerably after its introduction for lighting, remarkably rapid progress has been made in the development and adoption of domestic electric power and heating appliances, as is amply demonstrated by the two articles on these subjects in this issue.

Electricity in Household Service

PART I. THE SOURCE: THE CENTRAL STATION

By H. C. Hoyt

Lighting Department, General Electric Company

In a recent report on Public Service securities, we read that "electricity is one of the great potential factors of the universe, and electrical development is probably making greater strides than any other branch of science or adjunct of civilization." Electricity is grandly impressive in the big things it does, but the wonder of it lies in its ability to serve at the same time the more intimate needs of the home. It lights thousands of humble cottages with the same incomparable light that shines forth in the most pretentious mansions—a light that far surpasses in simplicity, convenience, and quality any illuminant that served the kings of old. This is its commonest household use; but at a small cost this versatile agent may be made to perform the many chores that are a drudge to housekeepers. Some of the ways in which electricity can be employed in the home are outlined and illustrated in this series of articles.—Editor.

The phenomenal growth of the central station industry, since its modest beginning in 1880, amply proves the assertion that it has now become a necessity in the economic life of the country second in its importance only to our transportation systems. There are today in the United States 5500 central stations doing an annual business of well over $500,000,000, and supplying service to something over 9,000,000 consumers, 5,800,000 of whom are lighting customers. The total output of central stations for 1917 was approximately 28,000,000,000 kw-hr., over half of which was developed by hydroelectric power. The growth of the industry during the last 15 years may be judged from the statistics given in Table I.

TABLE I

	1902	1907	1912	1917[*]
Total Number Central Stations	3,620	4,714	5,221	5,500
Investment in Construction and Equipment	$504,740,000	$1,096,914,000	$2,175,678,000	$3,000,000,000
Total Number of Employees	30,326	47,632	79,335	125,000
Total Gross Income	$85,701,000	$175,642,000	$302,116,000	$550,000,000
Total Income from Electric Service	$84,187,000	$169,615,000	$286,981,000	$500,000,000
Total Generator Capacity in Kilowatts	1,212,000	2,709,000	5,135,000	9,000,000
Total Kilowatt-hour Output	2,507,051,000	5,862,276,000	11,532,963,000	28,000,000,000

[*] Approximate.

There are about 11,000 communities in this country where electricity is available for service in the home as light, heat, or power, as against 3500 communities which are served with either natural or artificial gas.

In 1907, the average candle-power of incandescent lamps was 18 and the average wattage was 52. In 1917 the average candle-power had increased to 48 and wattage decreased to 48; or, in ten years, a gain of over 200 per cent in the amount of light obtained for a given cost. In 1917, there were sold 165,000,000 large size incandescent lamps and 75,000,000 miniature lamps.

Twenty years ago only about two per cent of the total electrical energy in the country was supplied by central stations. Today approximately 33 per cent is purchased from central station systems, furnishing power for approximately 10,000,000 h.p. in electric motors.

It has been estimated that fully 70 per cent of the population of the country is in some way affected by the use of electrical energy. On the basis of five persons to the average family, central stations directly serve a population of approximately 50,000,000, and this is accomplished at an expenditure of less than four per cent of the total coal consumption of the country. Only about one per cent of the total coal output is used for electric lighting.

In these days when every endeavor is being strained toward maximum production and the conservation of our resources, the economies offered by central station service are a source of pride to all those connected with its maintenance. In the larger plants, less than two pounds of coal are required for the production of one kw-hr. of energy; while in the small industrial plant where the generating of electrical energy is in the nature of a by-product, it requires from 15 to 20 lb. of coal to produce the same amount of electrical energy. The natural result is a decided tendency toward the forcible closing down of these small plants and the transferring of their load to central station systems as an essential part in our fuel economy policy of today. In addition to this, many of our larger systems are being interconnected in order to secure the advantage of a more uniform load through the balancing of the maximum demands of one locality against the smaller requirements of another district during the same hours and to permit the full utilization of hydraulic power in spite of variations in seasonal flow on adjacent watersheds.

In the small municipal plant or central station generating energy for purely lighting load, it has been estimated that half of the entire generating capacity is required for service only one tenth of the time. In other words, fully 50 per cent of the plant equipment is held in reserve or operated only about two and one half hours a day. A comparison of this estimate with statistics for the larger systems, serving a diversified load for lighting, street railway, and industrial power, is startling. In 1917, a total of 45 of the largest central stations generated over 21,750,000,000 kw-hr., or nearly 80 per cent of the total output for the entire country. Included in this number were such plants as the hydroelectric stations at Niagara Falls which operate on a nearly continuous 24-hour power load, and steam plants similar to those of the Public Service Company of Northern Illinois which supplied only about nine per cent of its total output for residence service.

It is this large capacity in generating equipment, lying idle much of the time, which prevents further reduction in lighting rates by small stations. On the other hand, it is the combining of power loads by day and lighting loads by night which enables the large central station to utilize a greater proportion of the generating equipment continuously, and not only to reduce their lighting rates but to offer power rates for manufacturing purposes at a figure with which the small industrial plant cannot compete.

Still another potent reason for the development of large central stations is in the matter of efficiency. The average efficiency for the conversion of mechanical to electrical or electrical to mechanical energy is 90 per cent, and this percentage is considerably increased for large units. In fact, as high as 96 or 97 per cent has been reached in some of the largest generators.

In the transformation of heat from burning fuel into mechanical energy the efficiency is much less, due to the inherent limitation that the mechanical energy developed can be no greater than the ratio of the absolute range temperature utilized in the boiler to the actual range of temperature utilized in the steam engine or turbine. Here again, however, large units approach much more nearly to the ideal condition, and especially is this true in the case of steam turbines. The first large steam turbines used in this country were installed in Chicago in 1903. They were of the vertical type, with a capacity of 5000 kw., and were guaranteed to give a Rankine cycle efficiency of 50.2 per cent. In recent years 35,000-kw. horizontal turbines have been installed which were guaranteed to give an efficiency of 76.3 per cent. These latter units developed an over-all thermal efficiency of 10.15 and 20.75 per cent respectively. Probably the highest efficiency ever secured for large reciprocating engines was in the case of the horizontal-vertical cross-compound engines of the New York Edison Company, which developed a Rankine cycle efficiency of 56.2 per cent. But this efficiency cannot even be approached in smaller units.

Fig. 1. The first large steam turbine (5000 kw.) was installed in a Chicago central station in 1903. After years of exceptionally satisfactory service, it was replaced by very much larger and more efficient turbines, and now stands in front of the turbine building, General Electric Company, Schenectady, N. Y., as a monument to the achievement of its day.

The margin which still exists between peak load and average load is illustrated by the typical load curves shown in Figs. 2 and 3, which represent practically maximum conditions for two of the larger central-station systems. Fig. 2 also illustrates the proportion of the total load furnished for railways, other utility companies, and commercial light and power. Fig. 3, in addition to being a typical load diagram, shows the reserve capacity in generating units held to meet emergency conditions and to insure continuity of service.

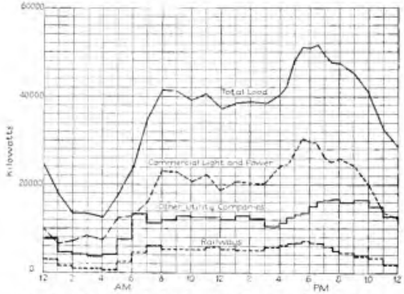

Fig. 2. Typical daily load curves of a central station showing total demand and segregated demands of various classes of consumers.

In its best sense, the central station sells not power but service, and it is the ability to furnish this service at any and all times which is mainly responsible for the growth of this industry. Not only must reserve capacity in generating units be installed, but usually multiple transmission lines are necessary from the generating stations to the distribution centers. In the case of large thickly populated districts, these multiple lines are expanded to form an inter-connected net work, tying in the various power and substations so that not only can the load be equitably divided between the generating stations, but in case of trouble on any feeder circuit power can still be transmitted over other lines to the same center of distribution. In addition to this interconnection of main feeders, the distributing lines are also interconnected wherever the density of population renders such a course feasible.

Some conception of the tremendous amount of power which must be handled can be gained from a realization of the fact that in some central stations there is concentrated a total of nearly one quarter of a million horse power.

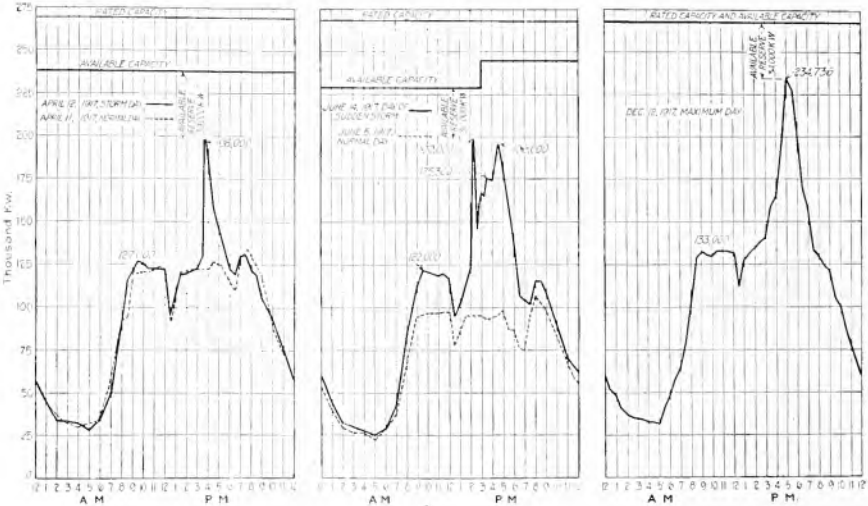

Fig. 3. The ability of the large central station to furnish an unfailing service to the household is indicated by these actual load curves which show that the available capacity of the station considerably exceeds even those sudden and exceptionally heavy demands occasionally made upon it.

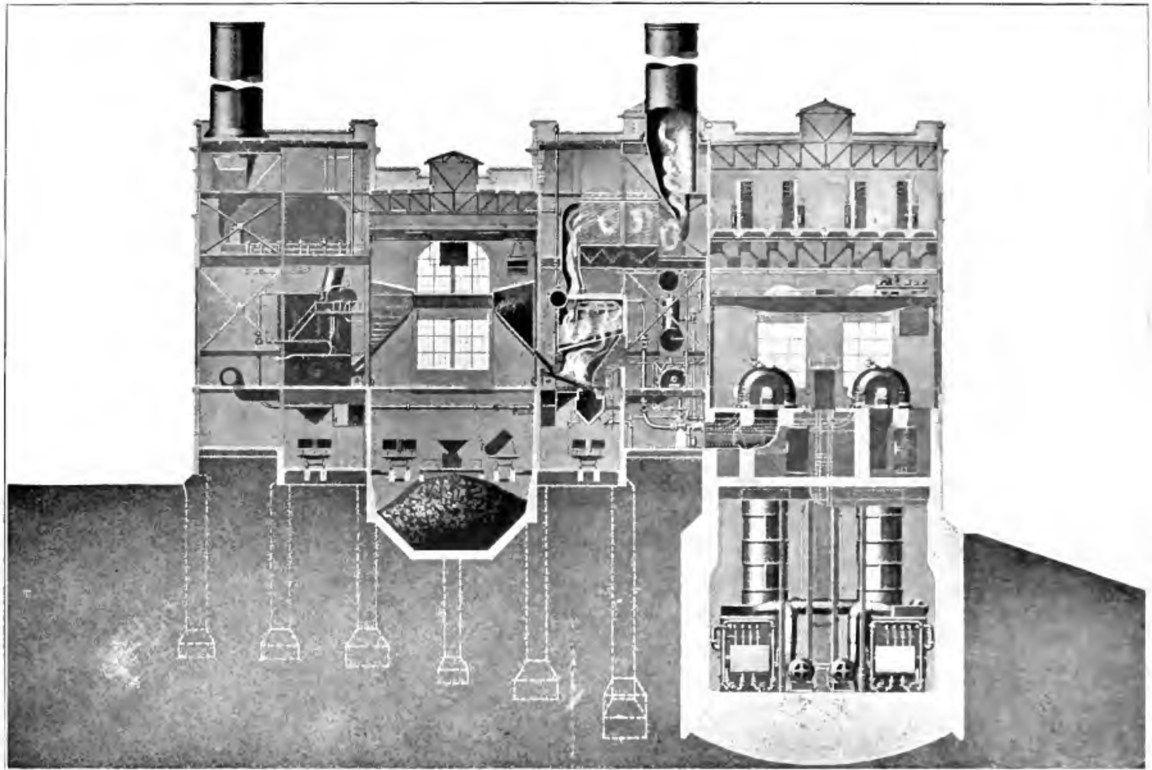

Fig. 4 Cross-section of a well-designed central station. Truly a great industry is back of the supply of electric service to the home

The generation of such quantities of power, often in the heart of thickly populated districts of our larger cities, requires a skill in operation and a care in the design of the station which have called for the ablest efforts of the best engineering talent in the country.

The ability of the central station to furnish service to the household when called for demands careful consideration of the growth of the district served. Not only must the probable increase in population from year to year be predicted, but the direction of this growth in any particular locality must be foreseen to insure the purchasing of additional generating and distributing equipment and the extending of transmission lines, plans for which must often be made even a year or more in advance of their expected use.

So many variables enter into the cost of furnishing power that any standard of rates, or even a method of charging for service, cannot apply to the country at large. The old flat-rate charge per lamp or per month has given way to the more equitable plan of charges based upon the amount of electrical energy actually consumed by each customer, but this again varies with the amount of such service. For the small domestic consumer, the minimum charge per month under the present basis is often less than one dollar. There is a strongly defined trend toward the theory of a minimum service charge plus a further charge for actual energy consumed. The justness of this plan can better be realized if one considers that the small consumer in paying less than one dollar per month is practically getting his electrical energy free of charge, as the amount of his monthly bill barely covers his proportion of the accounting and overhead expense of the central station and leaves nothing as his contribution toward the actual expense of fuel, generation, and transmission of power.

The question of power rates for large consumers involves the consideration of very different factors. In many cases, the central station must stand ready to furnish power on demand far in excess of the average requirements and, unless stipulated to the contrary in the power contract, such demand might occur at a time when the station was operating at its maximum output. Furthermore, the application of the energy supplied to large users is a question which greatly affects the generating station. While energy furnished for lighting purposes only does not entail a hardship on the central station, on the other hand, a load composed largely of induction motors or similar devices, operating at poor power-factor and in many cases at partial load, results in a demand for central station energy which is not reflected in the readings of power delivered to the customer's lines.

All these questions involving maximum demand, time of such demand, and the nature of the load must be considered in determining an equitable rate of charge for the service rendered. Minimum rates are offered for constant load, for off-peak load, and for

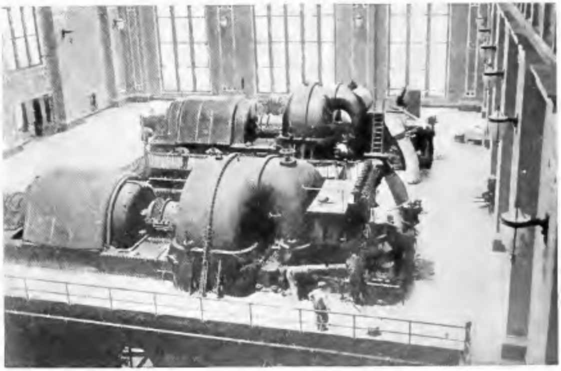

Fig. 5. Generating room of a central station showing two 25,000-kw. Curtis turbine-driven generators

loads of good power-factor. Penalty in the shape of increased rates must be charged if the central station is forced to maintain extra capacity in generating units, to cover possible heavy demands or the effects of low power-factor or efficiency.

It has been claimed that hardly one house in three on the transmission lines of central stations throughout the country is completely wired for electrical service. While it is exceptional for a new dwelling to be constructed within the district served by a central station without being wired for lighting service, there is still a surprisingly large number of the older houses which are not wired for electrical service of any kind. The discovery of such houses and a campaign to promote the installation of electrical service therein is one of the largest fields of endeavor for the lighting solicitor. The arguments in favor of electric lighting are so obvious that the only reasonable excuse for failure to make the change will be an unwillingness on the part of the householder to finance the very moderate cost of such an installation, and even this argument has been in many cases combated by the central station through an offer to wire old houses and bill the cost by monthly installments in addition to the charge for energy used.

Next in importance to the securing of new lighting customers is the increasing of central station revenues through the sale and use of current-consuming devices. In over 4000 communities, special rates for electric cooking and heating, of five cents or less per kw-hr. are quoted; and nearly half of these communities are east of the Mississippi River. The fact that over 25,000 electric ranges have so far been installed is an indication of their growing popularity. In addition, there are fully 10,000,000 domestic electrical appliances in use today.

The manifold use of these appliances produce such economies, to say nothing of cleanliness and convenience, as to warrant the prediction that one of the [illegible] fields of service which the central [illegible] offer the domestic consumer [illegible] the use of electrical appliances and the creation of new demand [illegible] in the household.

Fig. 6. Interior of one of the largest central stations, a considerable portion of the output of which is consumed in lighting the home and lessening the work of its maintenance.

The expansion of the central station industry has been due chiefly to economic reasons. To be able to furnish electrical energy more cheaply, and with greater reliability than is possible for the small isolated plant, assures the development of central-station service in constantly increasing measure. As the population of the country becomes more concentrated, and with the increasing tendency of Public Service Commissions, and other rate-making bodies, to recognize the legitimate needs of central stations for financing their constantly enlarging systems and securing a fair rate of return on their invested capital, the outlook for the growth of this industry is most promising.

Electricity in Household Service

PART II. LIGHTING

By Evan J. Edwards

Electrical Engineer, National Lamp Works of General Electric Company

Into the period of two score years has been crowded the development of the electrical industry; and closely associated with this development at every step—in fact, in no small way responsible for it—has been the development of electric lighting. Although the invention of a workable dynamo-electric machine preceded the practical application of electric lamps, as indeed it had to, the application of electricity for power purposes lagged considerably behind its application for lighting. This lag can be readily understood when we recall that in the early days the electrical transmission of energy in large amounts was far less readily accomplished than it is now, and, too, that a single large motor would demand an appreciable portion of the entire output of a small "central station." The use of electrical energy for power purposes became practical on a large scale only when the central station had been expanded to the point where its capacity was much greater than the energy required for any one machine connected to its circuit and when the transmission of energy could be readily accomplished—in other words, when the system became large enough to permit the law of diversity to operate. We find right now somewhat of a parallel in the case of small isolated plants for the lighting of country homes. These plants, usually of about 750-watts capacity, supply energy for lighting requirements with entire satisfaction, but their use for power purposes cannot be generally recommended except where the energy required represents but a fraction of the plant capacity.

In 1882, the central-station industry in the United States consisted, for a brief period, of a single plant having a capacity of 250 low-power incandescent lamps which operated at Appleton, Wisconsin.* The central station output of the United States in 1917 is estimated by the *Electrical World*† at 27 billion kilowatt-hours. Of this, perhaps a third, or 9 billion kilowatt-hours, is used for lighting. Of the lighting load, the largest single item, probably about one fourth, consists of residence lighting.

It is interesting to note how the cost of light has consistently decreased for a number of years prior to the great war. This decrease has been due to improvements in the efficiency of incandescent lamps, to decreases in their cost, and to decreases in the cost of electrical energy. Although it has been necessary recently in a large number of instances to increase the rates charged for electricity, it is safe to say that such increases

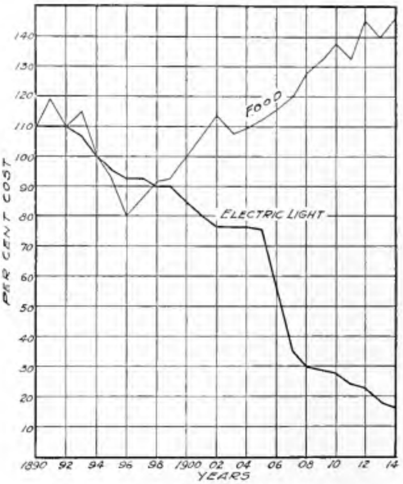

Fig. 1. Curves showing that while the cost of food commodities has been rising almost continuously, the cost of electric light has been steadily decreasing. Since the beginning of the war, the cost of food and light have both increased, but the increase in the cost of light has been very moderate

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* Samuel Insull, addressing the N.E.L.A. Convention at St. Louis, May 25, 1910.

† Electrical World, vol. 71, p. 2, Jan. 5, 1918.

have invariably been extremely conservative in comparison with the leaps and bound of prices of manufactured products in almost every other line of industry.

As electric lighting stands today, it is inexpensive, convenient, and safe. It is used in all classes of homes from the most humble to the most pretentious. In territories which are served by an electric utility company, the newly constructed home which is not wired is the exception rather than the rule. Where central stations have inaugurated campaigns aimed especially to interest the very smallest householder, we find that here, too, electricity has become the rule. Electric lighting is one convenience which is shared by rich and poor alike.

Ordinarily, we should expect that a commodity as commonly used as electric lighting would, quite naturally, like standard recipes, be properly used. In the home, this can hardly be said to be the case. The reason is probably to be found in the fact that electric light was first installed as a convenience and for the prestige which its use conferred. The sources which it superseded gave insufficient light for good general vision and hence were used almost [illegible] source. The [illegible] the center of a room provided [illegible] in its immediate neighborhood [illegible] served also to illuminate the room. [illegible] the standpoint of light [illegible] marked a considerable improvement. B[illegible] new factor, namely a small light source of high power, was introduced. The brilliancy of the filament was not at once recognized as undesirable, however, for the reason that glare works insidiously and the discomfort caused by the unscreened source was entirely ignored. With the decreasing cost of producing electric light, we find light used in greater and greater quantity. This in itself represents progress; but we find also that the brilliancy of incandescent lamps has been greatly increased and that adequate measures have not been taken, until recently, to combat the glare evil.

In the writer's opinion, the problem of minimizing glare is the one big problem in residence lighting today. To be sure, glare can be practically eliminated if we are willing to sacrifice the light-and-shade effects which we associate, unconsciously perhaps, with a homelike atmosphere; but to preserve the desirable features of our present systems and to eliminate the

Fig. 2 a. Electric lighting in a peasant's home in Trier, showing that this type of lighting is utilized in the most humble of homes

Fig. 2-b. Another example of electric lighting in a peasant's home Whether good or bad lighting is sold depends almost entirely upon the one who sells the fixtures. Neither of the fixtures in Figs. 2-a and 2 b screens the lamp from view. The one in Fig. 2-a is no better from a glare standpoint than a bare lamp, and it could have been made much better at no greater cost

glare is a problem which cannot yet be considered completely solved.

That form of glare which is due to an intensely bright light source in or near the direct line of vision—such as produced by a bare incandescent lamp suspended by a drop cord in the center of a room—has, with the development of reflecting equipment, become inexcusable. Some means should always be employed to screen the brilliant filament from the eye. The cheap frosted or stained glass shades which are in somewhat common use are of small value in this respect. The heavier translucent reflectors serve the double purpose of screening the filament from the eye and of redirecting a large part of the light which strikes them downward into the room. Semi-indirect bowls screen the filament from the eye and, if of large diameter and fairly dense, their brilliancy is not so high as to be objectionable if they are placed where they are outside the usual field of vision.

It is rarely, however, that one finds lighting units placed where they are not within the usual visual field. In the living room, for example, where the members of the family and their friends sit and talk for hours, we find as a rule a centrally located ceiling outlet. In those few cases where bare lamps are used, the discomfort is acute for there is little change for long periods of time in the position of the eye with respect to the brilliant filament. If frosted glass shades are used, only slight improvement can be noted. Dense glass bowl-shaped reflectors which extend well down over the lamp bulb modify the glare considerably; if the light source or sources are raised well up toward the ceiling, the glare may be hardly noticeable. If a fairly dense semi-indirect bowl of large size is used, glare will probably not be noticed at all. But experience has shown that glare may be

Fig. 3-a. Living room in an electrically lighted country home. Farm lighting plants are paving the way in rural districts for central station lines which sooner or later will be available

Fig. 3-b. Another electrically lighted room in a country home. The wiring, if properly installed, will require no change

present and be the cause of serious discomfort over a long period of time without ever attracting attention to itself. There may be some doubt about the degree of actual injury done by glare in its milder form but there is no doubt regarding the discomfort it can cause. A light source of very moderate brilliancy which is continually in view may work results more serious than one which, by attracting attention to itself, gives warning of its danger. For this reason, extreme care should be exercised in the selection of lighting fixtures which must be more or less directly faced, and wherever lamps are so used that they are visible, the bulbs should by all means be bowl-frosted.

A partial solution to the problem consists of dispensing with centrally located fixtures in those rooms where persons sit relatively still for long periods of time, and depending upon portable lamps; but this is hardly practical, for at certain times the rooms are used for purposes which require broad general illumination, which cannot be well supplied by portable lamps. A large semi-indirect unit located at one side or in the corner of a room would strike us as decidedly out of place now-a-days, but from the standpoint of vision, such an arrangement would possess some little merit.

At the present time, good living room lighting can be obtained by means of wall brackets and portable lamps supplemented by a centrally located semi-indirect bowl of large size and of fairly dense glass. For the quiet evenings, the portable lamps and the wall brackets will furnish illumination which is restful and satisfying, and the shadows will be found to beautify the room. An ample supply of base-board outlets will permit a wide variety of arrangements and effects. On gala occasions, where an appearance of brightness and sparkle is desirable, the center fixture may be called into service. But the tendency is to consider the central fixture supplementary to the brackets and portables rather than the reverse which has so long been the case. Somewhat the same treatment suggests itself for the lighting of the library or den.

There has been no fixture produced for dining-room lighting which gives results superior to those of the [illegible] familiar dome [illegible] A [illegible] room need not be flooded [illegible] of light. There should [illegible] of light on the table [illegible] throughout the room [illegible] considered desirable. The dining-room dome, if hung close to the table so that the diners cannot see the lamp within and high enough to permit unobstructed vision across the table, fulfills the requirements nicely. When semi-indirect lighting was introduced and actively promoted several years ago, the dome came to be considered old-fashioned and fell into general disuse. Semi-indirect fixtures of the usual designs are not, however, altogether satisfactory for dining rooms because of the fact that if hung high they produce undesirable shadows upon the face, particularly under the eyes; and if hung

Fig. 3-c. Dining room of an electrically lighted country home. The installations shown in Figs. 3-a, 3-b, and 3-c have all been in operation over five years; and good judgment was shown in the selection of the fixtures

Fig. 4. The central station and the electrical contactor should guard against replacing obsolescent illuminants with "drop-cord" units. In this home the change was from kerosene to electricity; and the installation, while not elaborate, has been made with a view to furnishing not merely light but illumination. **Note the convenience of the baseboard receptacles**

sufficiently low to avoid this objection, they are, in general, objectionable because of glare. In order that the advantages possessed by

Fig. 5. Portable lamps should be designed primarily with a view to the avoidance of glare. This lamp is designed to direct the major portion of the light to the ceiling whence it is diffused throughout the room, but sufficient light penetrates the translucent reflector to light the shade to a moderate brightness. See Fig. 6

the dome might be obtained without using a fixture considered out of date, many installations of cluster units have been made where very dense glass corresponding to that employed in the dome is used and the units are suspended well down over the table so that the lamp filaments are completely hidden from view. Recently there has been a tendency to revive the dome both in its old form and in somewhat modified designs.

The use of wall brackets [illegible] to lend an atmosphere [illegible] through the effect of light and [illegible]

Fig. 6. This photograph was taken by the light of the portable lamp. The lamp was built according to the design suggested in Fig. 5

general in homes where expense need not be kept at a minimum. However, incandescent lamps, no matter what decorative effect is

Fig. 7 The selection of lighting units and their location in the home is as much a matter of taste as the selection and arrangement of the furnishings. Light, shade, and color offer fascinating possibilities

sought, should never be used in such a way that the filaments are exposed to view, because of glare. In order to permit flexibility in the use of portable lamps and in the arrangement of furniture, plenty of wall or baseboard outlets should be provided. In fact, the installation of such outlets cannot be too strongly recommended, for the advantages of electric utensils, which take an important place in dining-room equipment, are completely offset if the inconvenience of attaching them for use outweighs their convenience in service.

In the living room, den, and dining-room are there particularly great possibilities in the use of color in lighting. In view of the fact that the appearance of all objects is greatly influenced by the color of the light under which they are seen, it is not surprising that we find the red, brown, and amber tones predominating in home decorations and furnishings designed to appear at their best under artificial lighting. The early flame illuminants generated light very rich indeed in rays of these warmer color tones. The carbon filament lamp, having much the same color characteristics as the light sources which it superseded, caused no disturbance in prevailing color schemes. The light from the Mazda lamp, while somewhat whiter than that of the carbon lamp, is also rich in the red, brown, and amber rays; and, fortunately, it is quite acceptable as regards color without any modification. However, the higher efficiency at which the Mazda lamp operates makes practical the filtering of the light to secure any color tone desired. The skillful decorator, instead of planning the furnishings of a room to suit artificial lighting of a single and fixed color value, may now select light of a tone adapted to any decorations he may elect to employ. The use of color in lighting is relatively new, but we may expect to see its influence to a greater and greater extent as the possibilities it presents become more generally appreciated.

Fig 8. The kitchen is the workroom of the home, and the lighting should be planned primarily for utility. The installation shown is above the average, but a person working at the sink or drainboards is handicapped by his own shadow Since this photograph was taken, a supplementary lamp and reflector have been installed just beneath the middle cupboard

In the kitchen, the problem is almost entirely one of providing utilitarian lighting;

Fig. 9. A dining room dome properly placed. The pleasant low-intensity illumination which fills the room has been almost completely lost by the camera

Fig. 10. In many old homes fixtures are altogether too prominent. Certainly a simple fixture which provides good lighting is much to be preferred

Fig. 11-a. Sometimes a marked improvement in lighting can be accomplished very simply. This illustration is typical of such an instance; the fixture as shown creates an objectionable glare. Compare with Fig. 11-b

Fig. 11-b. The lighting fixture of Fig. 11-a is here shown turned upward and the frosted shade replaced by a prismatic reflector which reduces the glare and throws the major part of the light to the ceiling which in turn diffuses it completely

color and the aesthetic effect of light and shade are not much involved. In a large room, it is desirable to install a centrally located unit to supply the general illumination and a supplementary unit over the sink and drain boards. It is frequently desirable to install an additional unit over the range. The central fixture should be kept well up toward the ceiling in order to avoid glare and in order that the shadows formed may be short. The supplementary units should be located well above the line of sight. In small kitchens a single fixture, centrally located, is frequently installed. If cupboards are built into the wall flush with its surface, a single unit so located will not produce seriously objectionable shadows; but if, as is often the case, cupboards are built out from the wall above the sink and drain boards, the recess so formed cannot be properly lighted from a centrally located fixture. In such cases, a small lamp equipped with an opaque reflector so mounted upon the bottom of the cupboard as to hide the lamp from the eye and direct the light downward will be found desirable. Prismatic glass reflectors of the distributing type are as good as any for the kitchen, although porcelain-enameled steel is coming into use to a certain extent. Here again it is well to suggest that plenty of wall or baseboard outlets supplied by heavy wire will facilitate the use of electrical appliances to lighten the work.

Fig. 12. The beautiful light and shade effects here shown are obtained entirely from portable lamps. The lighting may be rearranged as easily as the furniture

The bathroom is another location where the utility of the lighting is the first consideration. A common installation consists of a bracket fixture and a frosted shade, opening downward, above or at one side of the mirror. This arrangement almost invariably introduces shadows which make shaving difficult. If, as is usually the case, the room is finished in white or a light color, good results may be obtained by turning the bracket upward and using a prismatic or opal-glass reflector to direct the light to the ceiling whence it will be diffused throughout the room. Semi-indirect lighting, although little used in bathrooms at present, is highly desirable; and because of the preponderance of white surfaces to reflect the light, such a system does not entail the use of high-power lamps.

The lighting of the bedrooms should be designed to provide proper general illumination, good light for careful dressing, and local lighting for cases of sickness. A very desirable arrangement is a semi-indirect unit, centrally located, to provide the general illumination, wall brackets to provide illumination for the mirrors, and a portable lamp with a dense shade extending well below the lamps to provide the local lighting. Since the lights in the bedroom are used only for short periods of time, precautions to avoid glare are not so important as, for instance, in a living room. A small semi-indirect unit such as obtained by inverting an ordinary opal glass reflector is quite satisfactory, although beautifully decorated glassware is available at moderate cost. The reflectors used on the bracket lamps at the mirrors should, of course, screen the filaments from view. In many cases, the mirror lamps are made to supply the general illumination for the entire room. Where this is the case, good results can frequently be obtained by inverting the fixtures and making modified semi-indirect units of them. Baseboard outlets will be found very desirable in case of sickness even though a portable lamp does not form at all times a part of the bedroom furnishings.

Fig. 13. There is a tendency to revive the dome for dining room lighting. The one shown here is a modified form of recent design. The sharp shadow on the walls caused by the edge of the dome may be eliminated by using frosted lamps. Where the dome is used, care should be taken to see that the glassware is not lighted so brightly as to cause discomfort, and the unit should be hung sufficiently low to prevent the formation of unpleasant shadows upon the face

The use of bare lamps in the basement is almost without exception, but this practice is not economical because the walls and ceiling are so dark that very little of the light striking them is reflected back into the room. A dome-shaped steel reflector is well adapted to basement lighting. The reflector should be mounted as close to the ceiling as possible. How many units to use depends upon the size and arrangement of the basement. One unit over the laundry tubs and another near the furnace will often be sufficient. If the basement is used as a work shop, an additional unit should, of course, be installed. Switches which will permit the lamps, particularly the furnace lamp, to be controlled from the kitchen or back hallway are almost a necessity.

A porch light usually serves the purpose of a signal light and its equipment is unimportant as long as it prevents undue glare. A frosted or opal-glass globe and a low-power lamp comprise a satisfactory unit. Sometimes the house number is painted on the globe. Not infrequently very careful attention is given to the lighting of the porch. Lanterns of a design which harmonize with the architecture of the house are sometimes employed. But the important point to watch is that brilliant light sources are not exposed to view. Portable lamps will be found particularly convenient where the porch is used as an outdoor living room.

Fig. 14-a. This room and those shown in Figs. 14-b and 14-c are lighted by portable lamps only

Fig. 14-b. The large lamps shown in this room and those in Figs. 14-a and 14-c are designed to furnish totally indirect lighting, direct lighting, or a combination of the two in varying amounts

Fig. 14-c. An excellent control of light intensity and direction is obtained through the type of lamps shown in this room and described in Fig. 14-b

Fig. 15. The living room shown in Fig. 14-a as it appears under direct lighting supplied by the portable lamps. The small ceiling lamp is used to light the way when the house is dark

The lighting of the halls, like the lighting of the porch, is a matter entirely of taste as long as glaring light sources are concealed from view.

Between residence lighting and industrial lighting somewhat the same relation exists as between a painting and a blue print. And just as no rules can be given for painting a beautiful picture, so no hard and fast rules can be given for lighting a home. The statement has been made that the best way to light a home is to provide a large number of wall and baseboard outlets and a large number of portable lamps, and leave the rest to the judgment of a woman of taste. In a large measure this may be true, but where expenditure must be closely watched this procedure is hardly applicable, and it is necessary to do the best possible with equipment more readily available. Fixtures on the market permit a wide range of selection, and good designs are available at very reasonable cost. Equipment should be selected with a view to the avoidance of glare. It should be remembered that simple designs prove more desirable than elaborate ones in the long run, and, too, that the appearance of glassware may be very different lighted than unlighted. The contour of the reflecting surfaces should be such that light will not be pocketed and lost. The surface should be fairly smooth so that dust will not collect heavily and so that the fixture may be easily cleaned. It may seem unnecessary to mention cleaning in connection with a part of the household furnishings, but experience has shown that lighting equipment does not receive the attention in this respect that it deserves. A very slight accumulation of dust may decrease the intensity [illegible] 25 to 50 per cent, and the reduction [illegible] sufficient to spell the difference [illegible] adequate and inadequate illumination.

Fig. 15. Two outlets have been provided in this kitchen and if these were properly used good lighting would result. The cord above the stove should be considerably shortened, and both lamps should be fitted with good reflectors of opal glass, prismatic glass, or enameled steel.

Electricity in Household Service

PART III. MOTOR-DRIVEN DOMESTIC UTILITIES

By T. W. Behan

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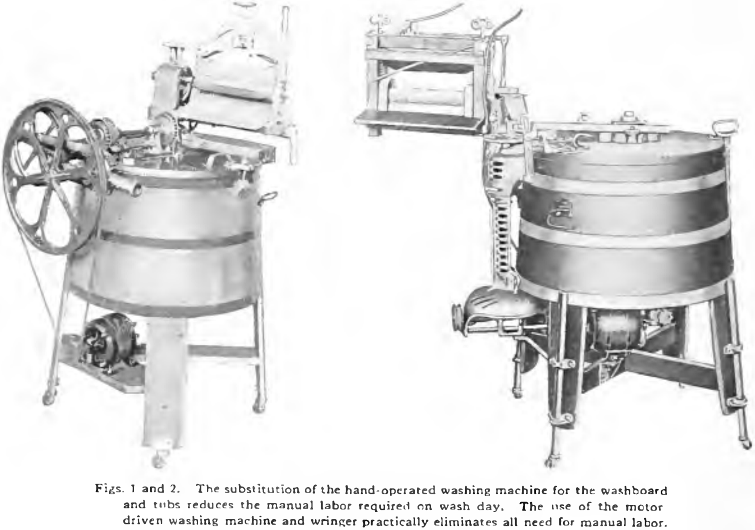
Electricity was originally introduced into the home for lighting purposes only. In a comparatively brief period of time, electricity outdistanced all other household illuminants, and at present is almost universally used. However, electricity was not immediately utilized as a motive power for household utilities. In fact, it has not been until comparatively recent years that such use has been made of electric current. This was due to a number of causes, the principal one being the inability of manufacturers of household utilities to secure for their devices satisfactory electric motors in the small sizes required. Other reasons, such as improper distribution of current, lack of proper wiring facilities, and a plentiful supply of servant labor which could be had at a relatively low cost, were operative in deferring the advent of electric motor-driven household utilities.

The first development of motors of fractional horse-power rating was the single-phase commutator motor for use directly on the lighting circuit. This motor developed a very strong torque at starting, and rapidly accelerated speed as the load was diminished. It proved very satisfactory for operating fans; and as a result, the fan was the first motor-driven household utility developed and made use of.

About this time, electric heating appliances such as the electric flatiron, electric grill, etc., were developed, and came to be used quite extensively. Such devices proved so satisfactory that a demand was made by the public for motor-driven household appliances which would lessen the manual labor incidental to housekeeping, a demand which was accelerated by the growing scarcity of servant labor. Accordingly, the manufac-



Figs. 1 and 2. The substitution of the hand-operated washing machine for the washboard and tubs reduces the manual labor required on wash day. The use of the motor driven washing machine and wringer practically eliminates all need for manual labor. These electrically driven washing machines are of the dolly type turers of domestic devices and the electrical motor manufacturers began to work together. Engineering experts soon developed a satisfactory constant speed alternating-current, single-phase motor which had high starting torque and sufficient acceleration for bringing its maximum load quickly to normal speed. This development in motors made possible the advent of the motor-driven washing machine which has been followed by the motor-driven ironing machine, vacuum cleaner, dish-washing machine, sewing machine, mechanical refrigerator, piano player, phonograph, vibrator, hair dryer, etc.

Fig. 3. Motor-driven washing machine of the cylinder type

Washing Machines

The washing machines on the market at the present time can be divided into four types: the dolly, the cylinder, the oscillating tub, and the vacuum cup.

The electrically driven dolly type of washing machine is a growth and projection of one of the original types of hand-driven washing machines. Its general construction consists of a conical shaped tub, in which an adjustable head having several projections is suspended and rotated in such a way that the clothes are carried backward and forward through the water until they are properly cleansed.

The cylinder type of washer consists of a main body of semi-cylindrical shape within which there turns a perforated cylinder in which the clothes are placed. The cylinder has internal lifting baffles for carrying the clothes to a maximum height from whence they are allowed to fall, as the cylinder rotates, into the hot suds contained by the main body of the washing machine. After the cylinder has rotated a number of times in one direction, its direction of rotation is automatically reversed, this scheme of operation being continued until the clothes are thoroughly cleansed. In this type of machine the clothes do not come in contact with the dirt which has been washed from them, as the dirt being heavy settles to the bottom of the washer where it remains undisturbed by the cylinder rotating above.

Fig. 4. Another cylinder type of motor-driven washing machine

The oscillating tub type of washer is designed with an elliptical shaped tub in which the water and clothes are placed. There are no baffles or rotating parts within this machine, the tub being simply tilted first toward one side and then toward the other in such a manner that the water is sprayed over the clothes first from one end of the tub and then from the other. This agitation of the water over the clothes to be washed thoroughly cleanses and removes the dirt from the garments.

In the vacuum cup type of washer, vacuum cups are mounted on a spindle which gives them an up-and-down motion, or in some cases a combined rotary and up-and-down motion. These cups are provided with release valves which open and let the air escape as the cups descend, and then close trapping the air as the cups rise vertically. The vacuum action of these cups draws the water through the clothes and thereby cleanses them.

It can readily be understood that the development of these several types of washing machines presented a more or less difficult motor application problem to the motor manufacturer. The problem was further complicated by the addition of the motor-driven wringer. It was found that a motor less than one eighth horse power was generally sufficient to operate the washing machine alone; but with the advent of the motor-driven wringer, the electrical manufacturer was confronted with this problem—the development of a motor which would drive the washing machine at a moderately constant speed with a relatively small power output under constant load conditions and, at the same time, be able to operate the wringer, requiring enormous torque, at a very low speed. It was found that the power or torque requirements demanded by the various types of combined washing machine and wringers varied widely. It necessitated a great deal of study and experimentation on the various types of washing machines with their combined wringers before a standardized design of motor was developed. The result of this investigation has been a motor of one sixth horse power rating, with a breakdown output of 175 to 200 per cent of full-load rating, a starting torque of 150 to 175 per cent of full-load torque, and an accelerating torque of 150 to 175 per cent of full-load torque. The motor must possess a high quality of insulation, in order that it may stand up under the unfavorable conditions of moisture with which washing machine motors have to contend. This insulating problem has been quite difficult because of the necessity of keeping the motor comparatively light in weight and small in size, in order that it may be easily portable and not add undue weight or bulk to the washing machine. It is absolutely essential that washing machine motors be absolutely free from "grounds," since current leakage might prove disconcerting to the operator.

Fig. 5. Motor-driven washing machine of the oscillating tub type

Fig. 6. Motor-driven washing machine of the vacuum cup type

The factors of power, speed, acceleration, insulation, and light weight have all been embodied to a high degree in the motors offered for this field of application at the present time. So satisfactorily have motors filled the requirements that in the last few years the demand for electrically driven washing machines has almost exceeded the supply.

Ironing Machine

It is a well-known fact that the ironing of the clothes is one of the most tiresome tasks to be performed in the home. It is true that the electric irons now commonly used are a wonderful advance over the old irons, which required the maintenance of a fire for heating them, but the electric iron has not eliminated all of the work incidental to the ironing operation. In the last few years, a motor-driven ironing machine has been placed on the market and has proved so successful that it might now almost be considered a necessary adjunct to the motor-driven washing machine.

The ironing machine consists of a semi-cylindrical stationary shoe arranged to fit the curvature of a cylinder which is rotated by means of an electric motor. This ironing shoe, usually heated by a gas flame, has a highly polished surface similar to the surface of a flatiron. Levers are so arranged that the shoe can be brought to bear upon the rotating cylinder with considerable pressure. The cylinder is covered by a thick wool felt, held in place by a covering of thin sheeting, and as the cylinder rotates it draws the garments to be ironed over the heated surface of the shoe Ironing with a motor-driven ironing machine is quite an easy and speedy operation; and as the temperature of the ironing shoe can be kept constant and the pressure between it and the cylinder can be varied as desired, the work turned out is especially pleasing. Ironing machines require a one eighth horse power motor to drive them; but as a rule, manufacturers recommend the use of the same type of motor for operating the washing machine and the ironing machine as the washing machine motor has demonstrated its ability to drive the ironing machine in an admirable manner.

Fig. 7. Motor possessing all the characteristics desirable for washing machine drive

Fig. 8. The application of motor drive in the domestic laundry is no longer limited to the washing machine and wringer. The power-operated ironing machine reduces to a negligible amount the work involved in ironing

Vacuum Cleaners

The electrically driven vacuum cleaner can now be considered one of the necessities among household labor-saving devices. Vacuum cleaning has for years been utilized in offices, public buildings, schoolhouses, apartments, and in some of the larger private residences; but the style of outfits used in these larger buildings were in general too expensive in first cost to merit their adoption in the usual size family home. However, vacuum cleaning had proved so effective that large vacuum cleaning plants mounted on wagons and hauled from house to house during the house-cleaning seasons proved wonderfully helpful to housewives in their semiannual cleanings.

Approximately ten years ago, developments were started along the line of the small portable vacuum cleaner. For several years after the first designs were placed upon the market, the public was slow to make use of them as their performance was not much better than that of the ordinary carpet sweeper, while their first cost was relatively much higher. With radical improvements in the driving motors and minor improvements in the cleaners themselves, the portable vacuum cleaner became a wonderful success and its introduction has been very rapid.

Fig. 9. The popularity of the vacuum cleaning process is its own recommendation. A high-grade portable motor-driven vacuum cleaner is one of the most useful implements in the household

Practically all of the portable cleaners offered to the trade today are built on the same general principle consisting of the motor, a fan and housing, a nozzle, and a dust bag. These cleaners are very light in weight, usually, not exceeding ten or fifteen pounds. Their construction is compact and such that cleaning may be done under furniture without the necessity of moving it. The motors operateat a very high speed, from 8000 to 9000 r.p.m., and develop approximately the same output on either direct-current or alternating-current circuits. They have been developed so that they will give years of service under adverse conditions; and due to the very large number of sales, several hundred thousand a year, the cost has been reduced to such an extent that every home where electricity is available can afford to purchase one of the various types of portable cleaners now on the market. In fact, the portable vacuum cleaner is rapidly displacing carpet sweepers and brooms. They certainly perform the cleaning operation in a much more sanitary manner, as there is no stirring up of the dust; moreover, upholstery, tapestry, walls, etc., can be easily cleaned with special attachments which are furnished by the cleaner manufacturers. Even the one objection to many of the electrical vacuum cleaners, (that they would not take up ravelings from the floor) has been overcome in the design of later cleaners by the addition of a rotating brush or oscillating comb in the receiver of the cleaner, so that now the higher grades of cleaner can be considered as practically faultless.

Fig. 10. The labor-saving benefits of motor drive have been extended even to the humble operation of dish washing, which for centuries has been performed by hand

Dish-washing Machines

The development of domestic types of dish-washing machines has not kept pace with the development of other domestic utilities, even though there is unquestionably a big field for devices of this character.

Two types of dish-washing machines are available at the present time; one making use of a propeller, while the other employs a centrifugal pump for the agitation of the water. In the propeller type, the water is thrown against the sides of the tub from whence it rises and, like a broken wave, falls in a heavy spray over the dishes arranged in a wire tray beneath. In the centrifugal pump type, the water is forced up through a tube in the center of the tub from whence it is sprayed forcibly over the dishes beneath. In order to obtain the necessary head and velocity of water in these dish washers, a comparatively large size motor is required (one quarter to one third horse power, depending upon the capacity of the machine). However, as the time of operation is comparatively short, the cost of operation is not excessive. Both of these types of dish-washing machines give a thorough and uniform cleaning of each and every dish contained in the tub. The drying of the dishes is accomplished by pouring extremely hot water over the dishes in the tray, a process which thoroughly sterilizes and drys them by the process of evaporation. Future developments can be expected toward the perfection of this domestic utility which will make possible a broader field for its adoption.

Fig. 12. Detachable type of sewing machine motor mounted in position

Sewing Machines

The application of motors to sewing machines has been carried on in a small way for several years. The original motors designed for sewing machine application were of the split-phase induction or the direct current type. Motors were designed for permanent mounting on the frames of the sewing machines and to be belted to the flywheel. These motors were put on the market to be sold to and applied by the users of the sewing machines.

Fig. 11 The application of motor drive to the sewing machine eliminates the fatigue caused by pedal drive. The under head type of sewing machine motor on the left has a self-contained control mounted on the motor case, the motor on the right has a separate control

The problem of sewing machine motor design has been somewhat involved because of the necessity for different arrangements in mounting the varied types of sewing machines on the market. Although the early designs of sewing machine motors required some skill on the part of the user to mount and properly operate them, they have given a degree of satisfaction which has stimulated a broadcast desire for the electrically operated sewing machine. Previous to the present time, sewing machine manufacturers have taken but little interest in the production of an electrically driven machine; but electrical manufacturers, realizing the possibilities of the field, have undertaken the task of producing motors which would be readily applicable to all kinds of machines. A high-speed, series-wound motor, arranged to drive the machine either by friction pulley or belt has lately been developed. The speed control of these series-wound motors is obtained through an adjustable rheostat in the motor circuit, the rheostat being arranged for control by foot pressure. The control and the operation of these motors have been solved very satisfactorily, a great many refinements having been recently introduced. The motors now offered are constructed in such a way that they can be easily mounted upon the machine without defacing it in any way. They will drive a properly constructed machine at the rate of six hundred stitches a minute, which is practically three times the speed of a machine driven by the ordinary method of operation. Furthermore, the machine can be suddenly stopped or accelerated, making it possible to do a great deal of work in a comparatively short time, and with the least possible fatigue to the operator. The demand for sewing machine motors has increased to such an extent that sewing machine manufacturers are now manifesting a great interest in electrically driven machines which shall have the motor built in as an integral part of the machine providing an outfit at once compact, portable, and inexpensive. It is safe to predict that such machines will be produced in large quantities in the not distant future.

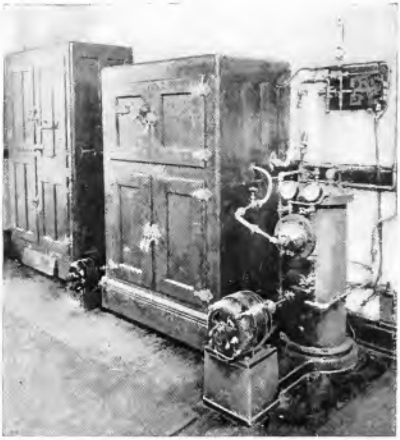


Fig. 13. The home furnished with a motor driven mechanical refrigerator equipment is not bothered by the troublesome ice man and his bills

Mechanical Refrigerators

Large commercial refrigerating plants have operated for many years since the extensive demand and distribution of perishable foods necessitated the establishment of large storage houses in which the temperature could be regulated. Although a great deal of thought and attention have been given the development of a successful small refrigerating machine for home use, but little has been accomplished in commercializing this proposition until the last few years.

The devclopment of a mechanical refrigerator for domestic purposes involves many difficult features; in the first place, the device must be absolutely foolproof and highly reliable, since it is impossible to give each installation frequent expert inspection. Moreover, the machine must operate with practically no noise since, when automatically controlled, it is likely to start operation at any period during the twenty-four hours. Also, the domestic mechanical refrigerator must not be too costly to install if it is to be within the reach of the average household, and the cost of operation must approximate the cost of the ice consumed in the refrigerators now commonly used.

The action of refrigeration in the mechanical machine is caused by the continuous cycle of evaporation, recovery, and condensation of the refrigerants. There are several different liquids available as refrigerants in the compression type of machines; the most commonly used being ammonia, carbon dioxide, ethyl chloride, and sulphur dioxide. On evaporation, the refrigerant absorbs heat from its surroundings. The gas, bearing the latent heat, is then drawn into the compressor where compression of the gas takes place with a corresponding increase in its temperature. In this heated gaseous form, it enters what is known as the condenser where the heat is extracted from the compressed gas either by running water or air, and the gas condenses or, in other words, becomes a liquid. This liquid is then passed through an expansion valve to the evaporator where it again absorbs heat from the surroundings.

The practical method for obtaining refrigeration in the home is either by the direct-expansion or the brine system. The direct-expansion system is one wherein the refrigerant is evaporated in coils of pipe, or other containers placed directly in the compartment to be cooled. In the brine system, the refrigerant on expansion cools a brine which is then circulated through cooling units located in the compartments to be cooled. The motor manufacturers' problem is that of producing a motor with the proper characteristics to accommodate itself to the load, which varies appreciably with the different phases of the compressor's operation, and at the same time runs with practically no noise. The noise feature can be appreciated when it is considered that the small integrating watthour meters operating on a practically negligible amount of power have been objected to when installed within homes on account of humming during operation. It is a much more difficult proposition to produce a one quarter or a one half horse-power motor which will run quietly enough so as not to be objectionable. The motor, moreover, must be capable of withstanding a very wide range of temperature; it must have an extremely low starting current in order that it shall not disturb incandescent lighting on the same circuit, and it must have bearings designed with very effective oiling devices as the motors are likely to be neglected and very infrequently oiled. In order that the operation of the machine shall be automatic, the motors must be controlled by a thermostatic switch adjusted to the desired range of temperature variation.

It is safe to predict that we shall see great developments in mechanical refrigerating machines within the next few years. Unquestionably the need of such machines is very great, a need which is increasing as the difficulties of securing ice increase every year. The mechanical refrigerator, moreover, has the advantage of giving lower and more uniform temperatures and dryer air in the cooled compartments than is secured where ice is used for refrigerating, besides freedom from the dirt and slime of the melting ice, and independence of the iceman's visits.

Exhaust Fans and Blowers

The electric fan in its forms of exhaust fans and blowers has many practical uses in the home. In certain cases, its use is almost a necessity. The blowers and exhausters mainly consist of an electric motor, the fan wheel or runner mounted on the shaft of the motor, and a metallic casing about the fan wheel furnished with exhaust openings. Much study has been given to the design of the fan wheels in order to make them efficient, light in weight, strong, and practically noiseless in operation.

The exhaust fan is very useful in removing the vitiated air, steam, and vapor from rooms, especially kitchens. It is usually mounted as high as possible, as the undesirable gases accumulate in the upper atmospheric layers of the room. The use of exhaust fans is highly practical during the winter months, when doors and windows cannot be left open for ventilation on account of the waste of heat. The exhaust fan is much more economical of the heat supply, as it removes only the upper layers of air which should be removed.

The small portable blowers find many other uses in the homes. If the furnace needs extra draft in severely cold weather, the blower can be placed in front of the furnace in such a position as to blow through the opening in the ash pit beneath the grate, thus forcing the furnace to increased efficiency and more heat. If the heat register in a room is not delivering its usual amount of heat, the blower can be placed beneath the register in such a position that the register discharges a greater volume of heated air. If it be desired to secure more heat from a steam radiator, the blower can be used to direct a blast of air over the heating surfaces, the heat being thus extracted more rapidly from the radiator, and consequently the room heated more quickly.

Fig. 14. Improved ventilation without drafts can be secured by a motor-driven exhaust fan or blower

For exhaust fans and blowers of the types described, the series motor is very satisfactory as the load is practically constant. Since the load increases rapidly with increase of speed, there is no danger of a properly designed motor running so fast that the fan wheel will be driven at an unsafe speed. The motor must be dustproof and very quiet in operation; furthermore, it must be highly reliable in order to operate for a considerable time with a minimum of attention.

Water Pumps

With the advent of modern residences in town and country came the requirement for water under pressure, available at the turning of a faucet. In cities with modern water systems, the domestic water supply under pressure has usually been adequately provided by the city water service. There have been instances, however, where there remained the problem of supplying soft water under pressure to serve the bath and laundry. In modern country residences, where city water service is not available, there was the double necessity of furnishing both hard and soft water under pressure. To solve these problems, the pump manufacturers in conjunction with the electric motor manufacturers have worked together to develop electrically driven water pumps which will supplement the city water service by supplying soft water, or, in the rural homes, will furnish both hard and soft water as desired.

Fig. 15. The phonograph manufacturer recognizes as annoying the necessity of having to wind this musical instrument frequently, and in consequence has tried to reduce the annoyance by causing it less often through the use of larger capacity motor springs in his higher priced instruments. Electric motor drive eliminates the necessity of winding altogether. The motor shown is of the spring winding type

This water system consists essentially of an electric motor, a water pump driven by the motor and connected by piping to a pressure tank from which radiate the pipe lines to the bath, laundry, and kitchen. As water is pumped into the pressure tank, air is trapped and compressed in the tank until the pressure is as high as desired. An automatic switch operated by the pressure in the tank then opens the motor circuit and holds it open until enough water has been drawn from the tank to reduce the pressure appreciably, at which time the pressure switch automatically closes the motor circuit and starts the pump.

The repulsion induction type of motor of approximately one horse-power capacity is best suited for operating the pump of such a water system. This type of motor has ample starting torque to start a pump against 50 to 60 lb. pressure, and moreover has the ability to deliver the requisite volume of water; these pump systems usually have a capacity of 100 to 150 gallons of water per hour, lifting it to a height of 120 feet.

The motor for this pump duty must be highly reliable and durable, as it is placed in a basement where probably it will receive but little attention. The winding must be moistureproof, since it is exposed to considerable moisture. The motor must be very quiet in operation as it is liable to function during any period during the day or night.

Piano Player

The development of the player piano created an immediate desire on the part of the public for a motor to operate the air pump. The very nature of the application calls for a motor of very special characteristics. The standard commercial alternating-current and direct-current motors proved to be unsatisfactory, since the magnetic hum and noise caused by the bearing and brush friction, etc., which are acceptable in ordinary applications, could not be tolerated for this purpose. Due to limits of space available for the mounting of the motor and to lack of ventilation in such mounting space, the difficulties incident to making a successful motor application were very severe.

Many schemes for eliminating the noise of the motor have been resorted to in the application of motors to player pianos, such as mounting the motor in a suspension cradle, or on a sound-insulating bedplate. Many of these arrangements which at first appeared practical were finally discarded, and the efforts of the motor manufacturers were directed toward designing a motor of very low magnetic densities and perfect balance in order to eliminate the mechanical humming and all other noises so far as possible. The alternating-current and direct-current motors designed for this specific duty are of constant speed characteristics, as motors of variable speed have been found inadequate due to the fact that the friction and the pump loads vary considerably with the different types of player pianos. Motors now offered to the trade for this class of application have been found to give highly satisfactory service. They have been built to be very reliable, in order that they may operate for long periods of time with very little care or attention.

Phonographs

Up to this time much effort has been expended on the development of a successful motor for operating a phonograph, even though the phonograph manufacturers themselves have not manifested any great interest in the production of an electrically driven phonograph. There are, however, a few persons who believe that electric drive for the phonograph is a good commercial proposition. They have encouraged the development o electric motors for phonograph drive, and are bringing the proposition more strongly to the attention of the phonograph manufacturers.

At the present time there are two well-known methods of making the application of the electric motor to the phonograph, both methods having their points of merit. In the first method, the motor is used to replace the hand crank. The second method of making the application is to mount the motor either above or beneath the phonograph turntable in such a manner that a friction pulley on the motor shaft drives the turntable through direct contact. A third development in phonograph motors has been lately introduced. This latter method eliminates the spring motor entirely and the phonograph turntable is driven either by direct connection or belt connection to the motor, the control being obtained by a centrifugal governor. The first method of making the application requires the motor to be small and compact, and yet able to develop sufficient torque to accelerate rapidly and wind the spring motor to a certain desired tension. The motor is controlled by an automatic switch which turns the current on and off automatically at predetermined tensions of the phonograph spring motor, the automatic switch being a part of the electric motor as


Fig. 16. Friction pulley type of phonograph motor

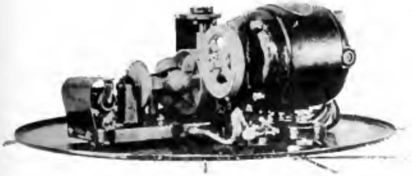


Fig. 17 Self-contained motor drive mechanism for phonograph

pressed which temporarily closes the motor furnished. The control in the second method mentioned is also automatic, but in this case it is secured by virtue of a centrifugal switch. When the motor is at a standstill, the circuit is open. To start the motor, a button is circuit


Fig. 18. The electric motor driven vibrator requires no recommendation to the mistress of the house: and its master finds that the device facilitates shaving operations and relieves his aching muscles

As soon as the motor reaches a certain speed, the automatic switch closes and keeps the contacts closed until the record is played, at which time the motor is stopped by a mechanical brake and the automatic switch opens.

The advancements achieved along this line of motor application are beginning to interest the phonograph manufacturers, and it is believed that much improvement and refinement can soon be expected along the line of electrically driven phonographs.

Vibrators

For the past fifteen years vibrators and massage machines have been on the market, but to a very great extent their use has been confined to the barber shops and the medical profession. Within the last few years, however, the sale of these equipments for home use has reached considerable proportions.

The standard vibrator consists of a small high-speed motor unit of convenient size to be handled without tiring the operator. The cup or applicator is given a rotary vibratory motion through the medium of an eccentric connection with the motor shaft. The motor is required to develop a very large output for unit weight and it must operate at a very low temperature. Special attention must also be given to the insulation, as any leakage would be very disconcerting to the operator. The device must be so designed as to operate satisfactorily with practically no attention.

Hair Dryers

The use of hair dryers, originally confined to hair-dressing parlors, is now becoming more frequent in the home. The hair dryer motor is essentially a small high-speed, series-wound motor as it is used to drive a fan which forces a large volume of air through the heating units, heated either by gas or the electric current. This application requires a design of motor absolutely free from insulation trouble, very light in weight, foolproof, and highly reliable, as the device will receive but little attention on the part of the operator.

Fig. 19. The lady of the house furnished with an electric motor-driven and electric heated hair dryer is never annoyed by having to wait for a warm sunny day or to sit with her hair wrapped in towels

Automatic Heat Regulators

Ever since the furnace system of heating was introduced in homes and public buildings, the design of an automatic heat regulator has been considered of vital importance. Since the advent of the furnace various schemes of levers and chains have been worked out so that the draft on the furnace fire could be manually controlled without making a trip to the furnace room. These devices have in the past been quite satisfactory; but now that it is essential that not a single unnecessary pound of fuel be burned, it is highly desirable that furnace fires be automatically controlled, as such a scheme properly applied should eliminate all unnecessary consumption of fuel and at the same time be a very great convenience. Accordingly, a very great deal of time and energy have been spent in producing a compact, practical, electrically driven automatic heat regulator.

This automatic heat regulator is a device which automatically opens and closes the dampers on the furnace, whether it be a hot water, steam, hot air, or a combination heater. The device is also especially applicable for regulating the temperature of buildings heated by steam from a central heating plant.

This regulator outfit consists of a thermostat and a small fractional horse-power electric motor with the necessary gears and levers to operate the dampers. The thermostat is placed in the room in which the temperature is to be controlled, and the remainder of the outfit is installed in the basement near the furnace. The thermostat

Fig. 20. A thermostat, in conjunction with the motor mechanism shown in Fig. 21, will assure the hot air furnace, steam boiler, or hot water heater maintaining the house at a constant temperature without personal attention to the dampers. The device shown can be set for any two temperatures—one for daytime, the other for nighttime—and the shifting from one to the other is accomplished by the eight-day clock

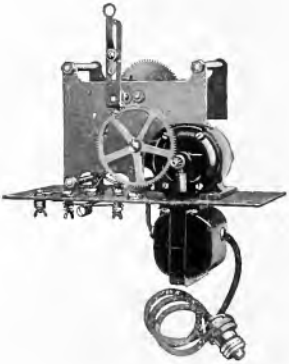


Fig. 21. Motor mechanism which changes the damper settings and which is automatically controlled by the thermostat shown in Fig. 20

which controls the operation of the whole mechanism is set for a predetermined degree of temperature, and as soon as the temperature of the room reaches that point, the thermostatic metal, bending with the heat, closes an electric circuit which by energizing an electromagnet releases a brake on the motor, thereby permitting the driving shaft of the motor to make a half revolution, which action closes the damper on the furnace. When the temperature in the room falls below the desired point, the thermostatic element again closes the circuit through the electromagnet, the motor shaft is again released and makes another half revolution which opens the damper.

The thermostat is in most cases furnished with a time attachment by which the temperature of the house can be changed to any desired degree at any predetermined time. Thus, it is possible to lower the temperature of living rooms automatically during night hours and to raise the temperature of such rooms to a comfortable degree just previous to the time they are to be occupied. By this automatic process, very uniform temperature is obtained, fuel is saved, and the life of the furnace is increased by preventing a hotter fire than is necessary.

The motors used to operate the mechanism will operate on either alternating or direct current, but where alternating current is to be used a small transformer permanently mounted on the motor base steps down the house lighting voltage to that suitable for use at the motor. The cost of operating one of these outfits for an entire season is extremely low. The motors for such service naturally must be very reliable and furthermore very quiet in operation as they may start to operate at almost any period of the day or night.

Crude Oil Burners

The relatively high prices of coal and the difficulties of transportation have stimulated the use of crude oil for use in the southern and southwestern sections of our country where the many great oil wells are found. At the present time a great many installations of crude oil burners have been made in the homes, apartment houses, hotels, office buildings, factories, etc. To a certain extent, such installations are scattered throughout the United States as crude oil can generally be purchased at a comparatively low cost which makes it competitive with coal as a fuel.

The crude oil burning outfit consists mainly of the burner and a small direct connected motor, for operating a blower and a rotary oil pump. The oil is pumped from a supply tank by the rotary pump into the path of the air leaving the blower. The oil then passes through an atomizer into the fire chamber, igniting as it leaves the atomizer. By this process a small volume of air at low pressure thoroughly mixes the oil and air into a combustible vapor for burning in the firebox. Approximately 1800 cu. ft. of air are used in the burning of one gallon of oil. The equipment permits of adjustment in the proportions of air and oil, so that practically perfect combustion can be assured. In operation, the burning of the oil is clean, there are no ashes or other dirt accumulations neither is there smoke nor any disagreeable odor. The outfits are very safe to operate as they are equipped with automatic circuit breakers and oil shut-off valves. Moreover, provision is made for electrical control of the temperature.

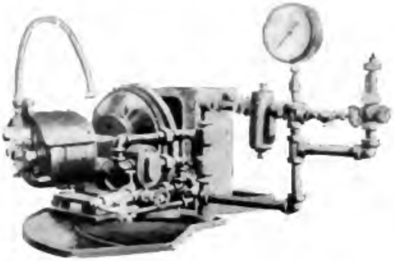


Fig. 22. The firing of oil has usually been limited to industrial or marine applications. This small oil firing apparatus enables this fuel to be burned in domestic heating furnaces

In this oil-burning outfit is used a one quarter horse-power induction motor which runs at the relatively high speed of 3600 r.p.m. It is made highly reliable, since its duty is continuous and practically no attention will be paid to it. Naturally the motor must be practically noiseless in operation, as noise would be objectionable at any hour of the day or night.

Kerosene Oil Burners

Much effort has of late years been spent in an endeavor to produce a satisfactory and economical kerosene oil burning system. But up to the present time such equipments have not been generally adopted, probably due to the fact that it has been cheaper to burn coal. With coal prices generally increasing and limited transportation facilities, there has been a greater amount of attention given to the development of kerosene oil burning equipment for domestic purposes. At present a system has been developed, which, it is claimed, can be operated at a cost equal to that where coal is used; such oil-burning equipments permit of better regulation in the temperature of the home and prevent overheating and consequently waste of fuel.

Fig. 23. A general utility motor which has a remarkable range of application to devices not motor-driven

Such a kerosene oil burning equipment consists of a small combustion chamber, a blower, and a float chamber. The combustion chamber is placed in the ashpit of the furnace. A cast-iron pipe projecting through the ashpit opening connects the combustion chamber to the blower. The blower is driven by a one fiftieth horse-power, series-wound motor which can be used on either alternating or direct current and is designed for connection to any convenient electric light circuit. The oil fuel is fed by gravity from a tank arranged beside the blower. As the motor starts the blower, the air at high velocity is forced through the outlet passage. As this forced draft from the blower passes through the outlet passage, it draws fuel from the float chamber and passes through the cast-iron pipe into the combustion chamber feeding it in a continuous spray of oil. The fire is started by a gas pilot flame located in the combustion chamber. The kerosene is burned in this atomized condition. Practically all the heat units contained in the oil are utilized. Provision is made to secure the proper amounts of oil and air. The motor operation is automatically controlled by a thermostat placed in one of the rooms to be heated. As soon as the temperature in the room reaches the maximum desired point, the motor circuit is opened and the fire is extinguished. As soon as the temperature falls low enough, the thermostat automatically closes the motor circuit, the outfit starts to operate and the fire is automatically ignited by the pilot gas flame.

The kerosene burning outfit requires practically no attendance. The fuel burns with practically no soot and with absolutely no ash, neither is there any disagreeable smoke or odors. These points of advantage are so much in favor over the crude oil burning system that additional improvements and refinements can be expected in the kerosene oil burners as the future demand grows.

General Utility Motors

In modern rural homes there are many devices such as washing machines, ice cream freezers, cream separators, grindstones and perhaps small shop tools, which while used only intermittently are very tiresome to operate by hand. It is very desirable to have in such homes a general utility motor for driving all such devices. For several years electrical manufacturers have considered this field for an electric motor, and have been working upon the development of a single-phase motor which would be practical for the drive of all of these miscellaneous machines. Many such general utility motors proved unsatisfactory and impractical when tried, as they did not have the proper electrical characteristics to adapt them to the driving of all the devices in question. As a rule, a comparatively high-speed, series-wound motor was the one tried out for this general utility drive. Such motors proved unsatisfactory because many of the machines should be driven at constant speed. A more recent development of the general utility motor promises to be highly satisfactory for this service. It is a constant speed motor and is standard so far as electrical characteristics are concerned, but as will be observed it is special mechanically. Three driving speeds are obtained in this motor by special pulley arrangements and reduction gears. The high speed is obtained from the small V-groove pulley directly mounted on the shaft of the motor at the commutator end. The belt is used upon this pulley when operating washing machines, cream separators, ironing machines, and similar utilities. The step pulley on the pulley end of the motor is geared to the motor shaft so that it runs at a greatly reduced speed. This step pulley is designed to take a flat belt on the larger diameter and a round belt on the smaller diameter. The belt is used upon one of these pulleys when driving such devices as the ice cream freezer, large diameter grinding stones, corn shellers, etc. Practically the same amount of power is given by these geared pulleys as is given by the small pulley mounted directly on the motor shaft, as the gear reduction is a highly efficient one.

The utility motor is mounted on a suitable tripod which allows for several inches of adjustment in height. This tripod is stabilized by means of a push rod which can be adjusted to press against the machine being driven, or to anchor to the floor, so as to react against the pull of the belt upon the motor pulley. If desired, the motor can be dismounted from the [illegible] and [illegible] be bolted to the wall, bench, [illegible] driven in the same manner as [illegible] motor. To facilitate moving [illegible] from one place to another it is [illegible] a carrying handle, the motor being [illegible] weight that it is readily portable. The motor is so constructed that it [illegible] reliable and can be used without [illegible] other than an occasional oiling of the [illegible] and gears. Especial care has been taken [illegible] construction of the gearing so that the [illegible] will run without making objectionable [illegible]

The Central Station Viewpoint

A general use of motor-driven domestic utilities means a considerable revenue to central stations, even though the devices are very inexpensive for the consumer to operate. This seemingly inconsistent statement is true because the power companies can take care of this additional electric service at practically no additional expense, as the motors for the devices can be connected directly to the house-lighting circuits without interference with the lighting service. Moreover, the load accruing from the operation of these domestic utilities is largely a day load, a load which is much to be desired by the operating companies. The field for such service is only limited by the number of houses wired for electric service, and the possibility of electric service meaning not only improved lighting, but motor-driven washing machines, electric vacuum cleaners, dish washers, and electric refrigerators will certainly tend to boost house-wiring campaigns.

Electricity in Household Service

PART IV. HEATING AND COOKING

By George A. Hughes

President of the Edison Electric Appliance Company, Incorporated

Development and Use of Electric Heating Appliances

"Edison's dream come true" has a fulfillment other than the one popularly associated with the present general use of his incandescent lamp. With prophetic foresight about 40 years ago he predicted that his new electric system would one day not only furnish electricity for lighting and turning the wheels of industry, but would be generally used for heating and cooking as well; and Thomas A. Edison is living today to see a remarkable fulfillment.

It is little realized that 20 or 30 years ago inventors were busy taking out inventions on electric heating and cooking appliances; but for many reasons the time was not ripe and the art did not develop. One of the greatest difficulties was to obtain the proper materials to make durable and satisfactory heating elements. Now designers have the nickel-chromium alloys, which have been developed in the last few years, with which to make their heating elements. These alloys are noted for two most important characteristics: a high degree of non-oxidizability at red heat and a high specific resistance.

We will not, however, stop to discuss the early causes that retarded the commercial development of the heating business or the more recent causes that have accelerated it; but will state that the last few years have seen a remarkable distribution of appliances and a development of the heating appliance business which has now grown to an annual volume of 13 or 14 million dollars, the product of 200 manufacturers. Heating appliances have passed out of the stage of mere luxuries or novelties and are staples of modern housekeeping. The government had occasion recently to review this business from the war priorities standpoint; and, after careful study of the surprisingly wide use which these appliances had reached and their place in the American household as conservators of fuel and of human effort, it was recognized that this business was an essential industry, with certain restrictions, and a peace-time necessity.

Even under the war conditions of 1917, a million flat irons found their way into homes to lighten the laundry burden and to save millions of miles of steps between the ironing board and the stove. It may be of interest to note the estimated number of electric heating appliances in use in the United States, as shown by Table I.

TABLE I

DOMESTIC ELECTRIC HEATING APPLIANCES IN USE IN THE UNITED STATES

(Estimated)

Grills	150,000
Heating pads	90,000
Teapots	10,000
Heaters and radiators	250,000
Irons	4,000,000
Toasters	480,000
Percolators	150,000
Chafing dishes	40,000
Disks	250,000
Ranges and hot plates	50,000
Water heaters	35,000
Miscellaneous	25,000
	5,530,000

Electric Cooking in Relation to Conservation

The subject of conservation is fresh in everyone's mind. It expresses an idea which has taken hold of the American public and it is hoped that it will be an enduring one. Electric heating and cooking appliances contribute in a very large measure to conservation.

The conservation of fuel is best illustrated in the electric range. No doubt one of the greatest wastes in the use of coal is in the home. Coal cook stoves are woefully inefficient in changing coal energy into cooking energy. By far the greatest amount of energy escapes up the flue and only a small fraction—about two per cent—cooks the meal. It has been conservatively estimated by some experts that the average family of five consumes, for cooking only, 800 lbs. of coal monthly, or nearly five tons annually. On the other hand, to supply this family with ample cooking current the central station burns 260 lbs. of coal per month, or only slightly more than one and one half tons per year—only one third as much. Thus, by means of electric cooking there might be saved to the country over three tons of coal per family per year.

The Society for Electrical Development has estimated that the 9,000,000 domestic coal ranges in the United States consume 90,000,000 tons of coal per year for all kitchen purposes. Now, if the central stations supplied all these coal-using homes with cooking current only, the United States would save 27,000,000 tons yearly. This, together with the saving by use of cooking current generated by the water-power central stations, would have gone a long way towards making up the annual coal shortage of 50,000,000 tons caused by the war. Besides, the housewives of America would have been relieved of the necessity of carrying at least 45,000,000 tons of coal yearly from their coal bins to the ranges, and of scooping up and carrying away nearly 10,000,000 tons of ashes. Untold millions of dollars annually go curling out of cottage chimneys. The little flakes of soot from your own kitchen range that lights on your nose as you start down town in the morning may seem to you like a trifling item, yet it represents enough waste every year to found and endow a great university for the people.

THREE-HEAT RADIANT GRILL

This grill has been justly called a "table range." It boils, broils, fries, stews, toasts, grills, and when provided with an auxiliary oven it bakes perfectly.

HEDLITE HEATER

A very effective as well as novel heater. The polished copper reflector is concave. This intensifies and concentrates the heat generated and delivers it much as a headlight delivers light, hence its name "Hedlite."

In further considering the estimate of the coal that might be saved by the average family, where a central station supplies the current, it should be borne in mind of course that many such stations operate by water power instead of coal and in such cases the saving by the use of electric cooking would be nearly five tons of coal per family per year.

The use of hydroelectric power is one of our greatest moves in the direction of conservation. The waste of this power is a waste indeed. Coal not mined today can wait for future consumption, but the millions of tons of plunging water represent a power that does not accumulate but that runs away to the sea. Saved to us, it would vastly aid all industries and effect enormous savings in our resources of coal, petroleum, and wood products. The little electric flatiron itself saves at least a quarter of a ton of coal per year, and, when it is considered that there are about four million flatirons in use, the annual coal saving is a million tons. This statement is based on the following: With a coal consumption of 2½ lbs. per kw-hr. at the central station, the flatiron will use 162 lbs. of coal per year, operating two hours a week. Ironing with coal- or gas-heated irons will require 50 per cent longer to do the same work because of the time spent in walking to and fro between the stove and the ironing board and looking after two or three sad irons. A coal range uses ten pounds of coal per hour when ironing, of which there may be credited one half to other uses such as heating, cooking, etc., and therefore it may be assumed that the annual coal consumption per iron is 750 lbs. Or, if the electric iron is compared to the gas-heated iron, there should be figured at least an annual consumption of 600 lbs. of coal to generate the gas required.

ELECTRIC MILK BOTTLE WARMER

The utility of the electric bottle warmer is obvious. It is sufficient to say that its utility is exceeded only by its efficiency.

Thus far we have endeavored to show how electricity conserves *things*. We will now briefly suggest how electricity conserves *people*.

The drudgery of hard work and long hours was the destiny of our own forebears, in the so-called "good old times;" and the vast work of running our modern civilization would be impossible with our own puny muscles. Some expert has said that the poorest machine in the world is the human machine. Considering the human body, mechanically, as a maker of products or as a renderer of industrial service, the modern tendency is to "junk" it, and to substitute a much more efficient machine, one made of metal and endowed with power from without, and then to put the human being in charge of that machine as manager.

This is conservation of the finest kind. It is releasing human effort for a higher and greater usefulness and greater happiness. These things must be realized in the home as well as in the office and factory, and to this end electricity with its many conveniences and appliances is of the greatest aid.

Just let us enumerate the many ways this modern Cinderella, Electricity, comes to perform the home drudgery. If the room is a little chilly in the morning, press a button and on comes the electric heat. To get the coffee ready, turn a switch and the electric percolator gets busy. To fry the bacon, here is the hot plate or radiant grill all stoked up and waiting, its fire drawn from a central station possibly miles away. Does the floor need sweeping? Here is the electric vacuum sweeper. Is it wash day? Behold the electric washer, and the electric iron. There are the children's dresses to make; well, there in the corner is the sewing machine ready to run all day and never cause a complaint of backache. For the meals of the day, the electric range will do all the work without watching, worry, smoke, fumes, dust, ashes, and soot. And as for sharpening knives, polishing silver, turning the freezer, running the meat- and the coffee-grinder, electricity is ready; just say the word, and the muscles of the coal mines and the tendons of the waterfalls come leaping across the land to do your bidding. At evening, instead of getting the old kerosene lamp ready, just press a button, and every dark corner is illuminated. During the night, if baby's milk needs warming or if grandma's feet are cold, the sun's energy that stored

ELECTRIC TOASTER
The picture shows a toaster which is the product of many years of study and experiment. This toaster is the last word in beauty, strength, economy, and durability.

GENERAL ELECTRIC TYPE TWIN GLOWER
This type of heater is very novel as well as useful. When in use it glows brilliantly. It keeps baby comfy while he is being bathed and dressed.

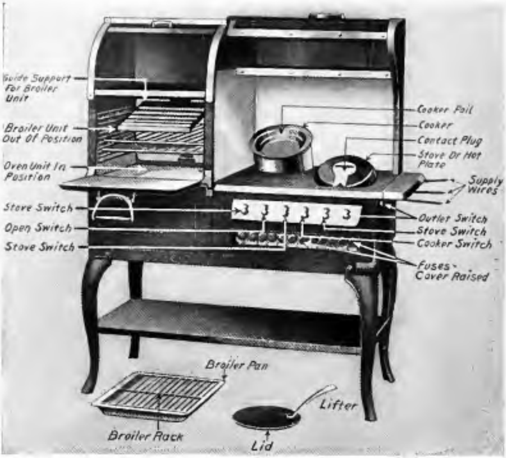
GENERAL ELECTRIC TYPE GRILL
This type of electric grill is probably the most efficient yet devised. Sturdiness, beauty, and efficiency, combined with economy, are responsible for its immense popularity.

ELECTRIC GRILL
It is possible, with the modern electric grill, to prepare breakfast from bacon and eggs to toast and coffee without leaving the table.

itself in coal a million years ago, brings almost instantly the benediction of its comfort.

Electric Heating and Cooking Appliances

Depending upon the purpose, various classifications may be made of electric heating and cooking appliances. There is one classification, however, which must always be borne in mind, that is, one of wattage consumption. This is a very practical one: not one of theory but "a condition." When household wiring came into vogue, and the fire underwriters began to make rules for house wiring, they decided that each branch circuit should be limited to twelve 55-watt lamps or a total of 660 watts. This rule is in force today and all house wiring and lighting circuits are arranged on this basis. This means that no flatiron, percolator, or other heating or cooking appliance which consumes more than 660 watts can be used on a lighting circuit. All appliances of higher wattage require special wiring and outlets. This, fortunately, has been no handicap to the electric flatiron, but it has been to many cooking appliances and to air heaters. The fact is that a kilowatt-hour generates only 3412 B.t.u. A 20-cu. ft. gas burner, for example, generates 10,000 or 12,000 B.t.u. per hour, and wastes most of these heat units. It is obvious that 660 watts does not represent enough heat units for many operations, even at the high efficiency at which electric heating appliances utilize this energy.



GENERAL ELECTRIC TYPE RANGE

An exploded view of one of the most modern types of electric ranges. This range is equipped with sheathed wire units. It spells doom for kitchen drudgery

Architects are beginning to realize the advantage not only in having convenient outlets throughout the house in baseboards and walls, but also in providing heating circuits with proper outlets, not only as a convenience in being able to add heating appliances to the household equipment, but in providing for the use of a separate meter and the possibility of a special heating and cooking rate per kilowatt-hour. For the purposes of this article, however, we shall confine ourselves to a brief description of culinary and other heating appliances.

Culinary Appliances

Culinary appliances may be subdivided into those for the dining room table and the kitchen. Table appliances have come into such vogue as to need hardly any description. By their convenience, appearance, and general acceptability they have introduced a new practice in American households, that of preparing coffee, tea, and toast, and performing other light operations, such as grilling, etc., on the dining room table. Here the hostess or other members of the family may prepare the food themselves to suit their individual palates, without going into the kitchen. It is true that percolators and chafing dishes operated by alcohol have been sold for a good many years, but in practice they were seldom taken off the buffet. Table toasting with the possibility of crisp piping hot toast served as you like it was never thought of until the advent of the electric toaster; much less the cooking of flap-jacks, or the grilling of chops, or the frying of breakfast bacon. The electric percolator may be largely credited with establishing the now quite general practice of making coffee by the percolating process, in which the coffee is not boiled or steeped, and in consequence a minimum of tanic acid is extracted and the lighter volatile oils yield their captured aroma to the coffee. It has recently become possible to obtain electric silverware in percolators, coffee urns, and hot water kettles in de luxe Sheffield plate to match the most beautiful dining room furnishings after the principal period designs, such as Chippendale, Adam, and Versailles.

Table culinary devices are not, however, limited to the dining room but are of universal household application; they may be attached to any lighting circuit outlet, especially in the den, nursery, or sick room. A "stag" luncheon can be prepared in the den. The *S O S* call from the nursery in the dark hours of the night may be quickly answered with the baby milk bottle warmer. The patient confined or quarantined in a sick room can be nourished with the nurse's own dietetic cooking.

Ranges

The electric range and its auxiliary, the kitchen tank water heater, are just beginning to receive the recognition which they deserve. From the standpoint of the cook or the housekeeper, the electric range is superior both to the coal and the gas range. With the latter, it is true, the trouble of lugging coal, of carrying away ashes, and of kindling repeatedly are eliminated and the heat is always ready at the turn of a valve and the lighting of a match; but the electric range is capable of positive control while the gas range is not. A far higher percentage of the heat energy is absorbed in the food in the cooking and baking operations and very little goes into the kitchen to make it uncomfortably warm in hot weather. The electric range is much cleaner and more sanitary to use. The uniform results that can be obtained with the electric oven and the hot plates is difficult to express in words, but it is greatly appreciated by the women who have used both gas and electric ranges. Then there is the question of shrinkage. Edibles in the electric oven do not tend to become dried out as they do in the gas range and the results are more like the old coal oven in the hands of the skilled cook, only the results are even better.

The introduction of electric cooking depends, of course, upon the electric station, its rates and policy. More than four thousand have published cooking rates of 4 cents per kw-hr. or better, and many have 3 cent rates. At the latter rate, electric cooking may be successfully exploited in competition with artificial gas at the usual rates. The principal electric cooking centers have been in the northwest, southern California, and eastern Texas; but include some of the eastern cities, like Milwaukee, Boston, and Wilmington.

ELECTRIC RANGE

The electric range is safe and sane, clean and economical. This picture is not exaggerated, inasmuch as it is perfectly safe for a child to operate it.

The evolution of the electric range has finally led to the standardization of a frame following the general lines of the gas range with ovens and hot plates similiarly arranged. Most of the electric ranges are of the cabinet style. Of course, there have been many changes in the construction of the gas range frame to adapt it for the electric wiring and connections of the heating elements, and in the thermal insulation of the oven. The construction is more expensive and of a higher grade. All of these features have been pointed out and discussed.*

Flatirons and Other Appliances

The present success of the electric heating appliance business may be largely attributed

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* "Some Features in the Design of Domestic Electric Ranges," by J. L. Shroyer, GENERAL ELECTRIC REVIEW, Nov. 1917, p. 889.

to the flatiron. The flatiron was the earliest appliance to come into general favor, and it performed such a distinctive service in the household that the way was opened for many other household appliances. Reference to the Table of Domestic Electric Heating Appliances in Use, Table I, will show that there are about 4,000,000 flatirons in use in this country. The increase in the use of flatirons has well kept pace with the number of houses wired. In fact, this matter of house wiring has seemed to be the only limitation to the business. One self-heeled electric flatiron, ready in a moment's notice, has replaced many millions of the flock of truly "sad" irons and their red-hot laundry stoves or kitchen ranges and eliminated the dreaded ironing day of the past. The only desired improvement or refinement in the electric iron seems to be the development of a really reliable thermostatic control or cut-out to prevent careless overheating.

Heaters

The electric heating of buildings has been prohibitive in operating cost, even at the most attractive rates, with one or two exceptions, but electric radiant heaters for connection to the ordinary lighting circuits have been quite popular, and in the last two years have sold by the hundreds of thousands. The idea of these heaters is, of course, not to heat the room but rather to heat the person by direct radiation. In fact, if it is merely a question of supplying the losses of body radiation in order to keep comfortably warm, only a few watts would be required; but the civilized human, especially in this country, wants to move in an atmosphere of warmth and so he has to supply the radiation losses from the entire building in which he is domiciled. However, quite a number of large-sized air heaters are sold each year for auxiliary purposes and for special applications. These heaters depend for their action on the setting up of convection air currents and the circulation of all the air in a room. They have the advantage of portability and of low operating temperatures.

Water Heaters

The introduction of the electric range has naturally brought up the matter of water heating for the kitchen tank; and various successful types of heaters have now been developed for this purpose. Those generally used are of two types: The circulation type and the clamp-on type. The circulation heaters are made in capacities from 600 watts to 5 kilowatts and are applied like the circulation type gas heaters to the kitchen tank. The 600- to 1000-watt sizes are used in places where a special flat rate is made for water heating, and they are intended to be in circuit practically all the time. The larger sizes are for intermittent use and are controlled by three-heat switches. The heaters for continuous operation are often used in connection with a range having a switch so arranged that the water heater will be cut out of circuit during the few hours that the range is in use. This arrangement cuts down the maximum demand on the central station.

OUTSIDE CIRCULATION

May be used in connection with any range boiler to maintain continuous hot water service—the modern way of "doing it electrically."

CLAMP ON

Strap this unique sheath-wire unit around any range boiler and turn on the current—it will keep hot water "always on tap."

The advantage of a circulation water heater lies in the fact that it takes the colder water from the bottom of the tank and delivers warm or hot water to the top where it accumulates until used; and a small amount of hot water can be had quickly when the tank is cold. It also has the advantage of connection to any standard tank, which special built-in heaters do not have. A comprehensive description of domestic electric water heating including specific data of the instantaneous, intermittent storage, and continuous storage types of heater has appeared in this magazine.*

The clamp-on heater was suggested by Mr. M. A. Osborne of the Washington Water Power Company at Spokane. It is intended for continuous use only. Its general advantage lies in its ease of application, for it may be strapped around a tank without interfering with the piping and without requiring the services of a plumber. It is also somewhat lower in first cost. There is a slight disadvantage in the case of a small tank when heating water electrically and the tank has become cold. This may be overcome practically by providing a tank of ample capacity, so as always to have some hot water in the tank.

Future for Electric Heating Appliances

An immense future for the domestic heating appliance business is predicated on the extension of electric central station service from the six to seven million homes now served to the possible twenty million, and to the intensive development among the homes now served; it is predicated on the great serviceability of electric heating and cooking appliances which is becoming increasingly appreciated, and on the great desirability to the electric station of the heating appliance and range load which will insure its being fostered and stimulated. We will doubtless see, in the near future, great activity in house wiring and new buildings; an activity which has been checked by the war until there is at present a great scarcity of dwellings. New sections will be built near the newer industrial plants, even new towns will appear on the map. It will not be easy for gas companies, in cities which have them, to compete for these new extensions.

With the per capita income in this country higher than ever before, campaigns on house wiring of old houses will open fresh outlets for heating appliances, and central station lines will reach out into districts never before served.

The opportunities for the [illegible] provided by electric heating [illegible] now fully recognized by [illegible] management who know [illegible] residence customers profitable.

Returning to the [illegible] customers already served with some [illegible] appliances, we need not point out the [illegible] creating increase of the number of [illegible] appliances per home, but we will [illegible] the greater possibility of the electric range of which only a comparatively few [illegible] are in use, compared with the number of electric flatirons for example.

The war put a check on the expansion of the electric range business just at a time [illegible] central stations were preparing to go into the business intensively or to expand their activities. Now that the war is over they will endeavor to make up for lost time. As has been stated in the foregoing, the recognition which the War Industries Board gave, that the production of electric ranges was essential on account of the savings made possible in food, fuel, labor, and transportation, and the fact that the use of electric ranges in certain locations was strongly recommended by various government agencies, will undoubtedly aid more in the introduction of electric cooking, as far as the public is concerned, than several years of propaganda under normal conditions.

Then there is the great servant question which the war has made more acute and which will continue increasingly to be a problem. Not only will this stimulate electric heating and cooking appliances in general, but many housewives forced to do their own cooking are adopting the clean and convenient electric range. This is especially illustrated in the South, where formerly the negro servant situation was an obstacle to the introduction of these appliances, but during the past year, there has been a decided change.

We may even predict that the servants themselves will soon be demanding the most improved and convenient kitchen equipment which can be obtained and which is found especially in the electric range.

The educational work already done on conservation has already made many people understand the advantages of electric ranges in effecting a definite saving in fuel and food. A tremendous business is therefore in sight for the electric range, and, in this magazine,† its economics and importance in central station development have already been set forth.

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* "Electrical Water Heating in the Household," by J. L. Shroyer, Oct., 1916, p. 556.

† "Electric Range Campaigning by the Central Station," by Hartwell Jalonick, Oct., 1917, p. 778.

Methods for More Efficiently Utilizing Our Fuel Resources

PART XXVI. RAILROAD ELECTRIFICATION AS A FUEL CONSERVATION MEASURE

By W. J. DAVIS, JR.

PACIFIC COAST ENGINEER, GENERAL ELECTRIC COMPANY

In the reconstruction of war devastated Europe, large quantities of coal and other fuels will be required, much of which must be furnished by the United States. Other raw materials and commodities produced in this country will also be in demand and must be moved to the seaboard for export. This burden on our railroads, in addition to our domestic transportation requirements, marks with special interest the subject of railroad electrification as treated in the following article which is an expansion of a paper read by the author at a joint meeting of the A.S.C.E., A.S.M.E., A.I.M.E., A.I.E.E., and A.C.S. late last year in San Francisco.—EDITOR.

In making a study of the possibilities of conserving our available supply of fuel through the electrification of the railroad systems of the United States, there are two points from which the subject may be viewed. These are:

(1) The possible saving that may be effected by the replacement of the steam locomotive equipment now in use with electric locomotives supplied with power from modern steam-electric generating plants of large capacity, suitably located with regard to cheap fuel and water and distributing over large areas through high-voltage transmission systems. (In their best use, these plants would not only serve the railroads but would supply power for all purposes in the districts covered by them.)

(2) The saving to be expected by comparing the possible performances of modern compound steam locomotives, using high superheat, with a system of electrification and power supply as above outlined.

Basing our calculations on pre-war conditions, it is found from the Reports of the Interstate Commerce Commission that the total gross ton mileage movements of the railroads in the United States for the year 1914 were approximately as given in Table I.

In estimating the gross freight ton mileage, it has been assumed that the net ton-mile movement of the freight alone will be approximately equal to that of the cars. This assumption applies of course only to the first four items.

If we assume that the complete electrification of our railroads is feasible and desirable, it is at once apparent that a considerable saving may be made in the total ton mileage as shown in Table I. In the third item of the table, Railway Company coal, the ton-mile movement may be reduced, as will be shown later on, to about one third by the greater economy of electric power generation, and a still further reduction will follow due to the location of many of the central power plants near the mines, and to the use of such hydro-electric power as may be available. It would appear fair to assume, therefore, that the ton mileage now required for the movement of Railway Company coal may be reduced to about 25 per cent of the third item, or to 14,400 million ton miles.

TABLE I

Traffic	YEAR 1914		POSSIBLE SAVING	
	Million Ton-miles	Per Cent of Total	Million Ton-miles	Per Cent of Total
1. Bituminous coal	166,400	15.93	.....	.....
2. Anthracite	38,200	3.66	.....	.....
3. Railway Company coal	57,600	5.51	43,200	4.15
4. Miscellaneous freight	372,040	35.65	.....	.....
5. Locomotives	148,200	14.20	19,500	1.87
6. Locomotive tenders	74,630	7.15	74,630	7.15
7. Passenger cars	186,890	17.90	.....	.....
Total	1,043,960	100.00	137,330	13.17
				Per Cent of Trailing Load
Total trailing load	895,760		117,830	13.12

The sixth item, ton-mile movement of locomotive tenders, may be eliminated completely. The saving in the third and sixth items will reduce the trailing ton mileage by 13.12 per cent, and a corresponding reduction is possible in the fifth item, locomotive ton mileage.* We, therefore, find that the total ton-mile movement of all of the railroads in the year 1914 would have been approximately 906,330 millions, if all of the roads were electrified, a saving of 13.2 per cent.

In estimating the fuel consumption of the electric power plants required for this movement, we can take as a basis for our calculations the results of some tests made on the Chicago, Milwaukee & Puget Sound Railroad, between Three Forks and Colorado Junction. The net energy consumption in a round trip over this section of heavy grades and curvature, using regenerative braking, was 23.75 watthours per ton mile at the locomotive, including power required for all of the auxiliary apparatus. The energy consumption of the same train on level track of the same curvature as determined from the known train weights, profile, and locomotive efficiency was found to be 20.4 watthours per ton mile. These results are of particular interest as they show that with electric locomotives and regenerative braking it is possible to eliminate a large proportion of mountain grades insofar as they affect the power required for moving the trains.

Assuming a transmission efficiency of 72 per cent from the power station busbars to the collectors of the locomotive, the energy consumption at the power house, using the larger test result as a basis, is found to be 33 watthours per ton mile.

Assuming then a total ton-mile movement of 906,330 millions, the energy consumption required by complete electrification would be 30,000 million kw-hr., to which should be added 20 per cent for [illegible] movement, and additional [illegible] suburban passenger [illegible] 36 million kw-hr. as a total [illegible] tion for the completely electrified [illegible] On the basis of an operating [illegible] 2.2 lbs. of coal per kw-hr., the annual fuel requirements for electrification would be 39.5 million tons of coal. The actual amount of coal consumed by the railroads in 1914, for locomotive use alone, including an allowance for fuel oil on the basis of 4 bbl. of oil per ton of coal, has been found to be approximately 120 million tons, or about three times as much, and the total saving to be expected in case of complete electrification would be 80.5 million tons. This is about one sixth of the total coal production of the United States.

Six 10,000-kv-a., 6600-volt Generators and two 500-kw., 240-volt Exciters at the Volta Plant of the Montana Power Company, Great Falls, Montana. This station supplies power to the Chicago, Milwaukee & St. Paul Railway

The point may be raised that the foregoing calculations are hardly fair to the steam locomotive, as we are comparing a highly efficient modern electric generating system with a variety of steam locomotives, many of them of old and inefficient types, and that modern compound steam locomotives using high steam pressures and high superheats might accomplish almost as great a saving as would be obtained by electric haulage. This

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* The ratio of the average weight of the locomotive to the weight of the train will certainly be no greater in the case of electric traction than with steam locomotives, even without the tenders, and it may be less. It would be difficult, however, to estimate this factor and arrive at an average value which would be at all accurate for various conditions.—EDITOR.

cannot be true owing to a number of factors inherent in the two systems, the more important of which are:

(1) The greater utilization of the available energy in the steam by the large central power stations due to condensing operation at high vacuum and the possible use of steam pressures and superheats beyond the established practical limits for locomotives.

(2) The improvement of load-factor on the power plant due to the generation of power for a large number of trains at a single plant and the use of central station power for industrial and other general purposes.

(3) The almost complete elimination of certain variable and unavoidable fuel losses inseparable from the steam locomotive. These are standby losses, waste of coal when forced draught is used, and excessive radiation losses in cold weather. These losses collectively are believed to average not less than 30 per cent of the locomotive fuel.

(4) The steam locomotive is essentially a single unit plant and as such must operate at a much reduced economy as compared with a central power station consisting of three to eight turbine-generators, each of 15,000 to 45,000 kw. and 10 to 75 boilers of large capacity. In the latter case, it is possible to operate the various elements of the plant at or near the rating for which they will give their maximum economy.

(5) By the use of CO_2 recorders, the losses due to excess of air in the combustion chambers of the boilers may be kept at a minimum in a large power plant. Close regulation of the air is impracticable on a locomotive.

The effect of these factors may be seen from a comparison of Tables II and III in which the economy of a large turbine-

Southern Pacific Electric Train: Alameda Division. Motor Cars each equipped with four G-E. 207, 600 1200 Volt Motors with Type M Control

TABLE II

CENTRAL STATION STEAM PLANT

Assumed steam pressure, lb. gauge	300
Superheat, deg. F.	250
Vacuum (30-in. bar)	28.5
Temperature of steam, deg. F.	672
Total heat above 32 deg. F., B.t.u.	1345.8
Available energy per lb. of steam, ft. lb.	340,500
Heat efficiency	33.8
Efficiency of turbine including generator losses, per cent	78
Efficiency of boilers, per cent	75
Thermal efficiency of turbine-generator, per cent $= 33.8 \times 0.78 \times 0.75 =$	19.8
B.t.u. per kw-hr. at generator $= \frac{3412}{0.198} =$	17,230
B.t.u. per kw-hr. at switchboard allowing 2.5 per cent for auxiliaries, etc.	17,660
Assumed load-factor, per cent	50
B.t.u. per kw-hr. output of plant at 50 per cent load-factor	21,200
Estimated lb. coal of 11,500 B.t.u. per kw-hr. output of plant	1.84
Assumed lb. coal per kw-hr. allowing for average monthly operating conditions, possible deterioration of plant efficiency due to bad water conditions and other causes, variations in operating personnel, etc.	2.2
Assume average efficiencies of transmission and conversion from power house to drawbars of electric locomotive as follows:	
Step-up transformers, per cent	98.5
Transmission line, per cent	95
Step-down transformers, per cent	97.5
Conversion apparatus, per cent	88
Trolley distribution, per cent	90
Locomotive, per cent	88
Combined efficiency power house to locomotive drawbars, per cent	63.4
Lb. of coal of 11,500 B.t.u. per drawbar h.p. hr. $= \frac{2.2}{0.634} \times 0.746 =$	2.59

TABLE III

COMPOUND LOCOMOTIVE WITH SUPERHEATERS

Assumed steam pressure, lb. gauge	225
Operating steam temperature, deg. F.	625
Superheat, deg. F.	227
Total heat above 32 deg. F., B.t.u.	1326.6
Available energy per lb. of steam, ft. lb.	184,500
Heat efficiency, per cent	18.5
Efficiency of engine (steam and mechanical), per cent	75
Efficiency of boilers, per cent	65
Efficiency from fuel to drawbar, per cent $= 18.5 \times 0.75 \times 0.64 =$	9.02
B.t.u. per drawbar h.p. hr. $= \frac{2550}{0.0902} =$	28,300
Assume load-factor, per cent	25
B.t.u. per drawbar h.p. hr. at 25 per cent load-factor	46,000
Assume standby and other unavoidable abnormal losses, per cent	30
Total B.t.u. per drawbar h.p. hr.	65,700
Lb. coal of 11,500 B.t.u. per drawbar h.p. hr.	5.71

generator station, operating under steam conditions demonstrated to be commercially practicable, is compared with that of a high-grade compound locomotive working at the maximum practicable steam pressures and superheats.

Chicago, Milwaukee & St. Paul 3000-volt Direct-current Electrification. Freight train, 1450 tons, west bound at Donald Summit of the Rocky Mountain Divide

It will be seen from these tables that highly efficient compound non-condensing steam locomotives of modern type operating in railway service as it exists today would be expected to use about 2.5 times as much fuel as required by an equivalent electric system. If we assume the total fuel requirements of the two systems to be in the ratio of the estimated economies shown, with allowances for reduced ton mileage in the third, fifth, and sixth items of Table I, the saving in fuel on this basis for 1914 would have been 73 million tons.

New York Central Railroad Electrification. Twentieth Century Limited, nine-car train hauled by Locomotive No. 1166

It is believed that this comparison is conservative, as no advantage has been taken of the possibilities of improvement in steam power plant economy by the use of higher steam pressures or superheats. There are a number of large steam power plants in this country now operating under [illegible] average of less than 20,000 B.t.u. per [illegible] at the switchboard. The assumed distribution and conversion efficiencies are also within the limits of well-established conditions of design and operation.

In the steam locomotive calculations, the efficiency of the engine includes all frictional, condensation, and radiation losses in the engine when operating under normal conditions. The standby losses cover the fuel required to kindle and clean fires under boilers, and maintain the steam pressure when the locomotives are standing or in a condition where no steam is being used for locomotion. A small allowance has also been made for losses due to extreme cold weather and abnormal forced draught conditions.

In our final consideration of the possibilities of fuel conservation by electrification of the railroads, we must not overlook the fact that in large steam power plants it is feasible and often economical to burn low-grade coals, whereas the steam locomotives require the higher grades of selected lump coal. This will release a large part of our highest grade fuel which may be applied to our growing merchant marine demands and to household uses.

Methods for More Efficiently Utilizing Our Fuel Resources

PART XXVII. FUEL FOR THE MERCHANT MARINE

By F. Parkman Coffin

Research Laboratory, General Electric Company

The operation of our huge merchant marine, now being built to be commensurate with the extent of our foreign trade, will consume large quantities of fuel. The present plans specify oil for this purpose; but we should investigate the adaptability of powdered fuel for marine use in order to relieve the drain on our limited petroleum reserves. Such investigation can best be made at the fuel testing station of the Bureau of Mines in Pittsburgh. The author has been making a study of this problem for some time, in co-operation with Mr. Hudson Maxim and other members of the Naval Consulting Board, and below gives a comprehensive review of the principal problems involved in connection with the preparation, handling, and burning of powdered fuels on shipboard. Among the important advantages of semi-coke are its safety in storage and handling and the fact that it can be made by carbonizing lignite and many low-grade coals which are more widely distributed than high-grade coals.—Editor.

Now that the war is over we can return to the problems of peaceful industrial and technical progress with some new points of view. The demands of war traffic have shown us the inadequacy of our transportation facilities by land and sea, and the lesson has been brought home to us as it could have been in no other way.

The congestion on our railways had a serious effect upon our coal deliveries, and coal is a fundamental necessity for both industry and transportation. The coal famine of last winter, and the scarcity of coal in some places at the present time, provide an object lesson which has awakened public interest in the matters of fuel supply and economic fuel utilization. Therefore, it should be easier to initiate research work that may lead to the development of methods for improving these conditions in the future.

The Merchant Marine

For oversea transportation we were much worse off than by rail. At the beginning of the war in Europe we were almost entirely dependent upon foreign shipping. Many ships were withdrawn from trade routes for other service, and others were sunk by German submarines. All German ships were tied up in port for years. We are now committed to the policy of building up a strong American merchant marine, and we are building ships for economic permanency.

American shipyards are now turning out new tonnage at a greater rate than those of any other nation, and we are planning to build some 13,000,000 tons.

These ships will require fuel, and plenty of it. American seamen receive higher wages than those of the nations with whom we must compete for our fair share of overseas trade. This means that our ships must be equipped with every available labor-saving device. The worst labor conditions to be found anywhere are in the stokehold of a coal-burning ship. Practically all the coal burned under ships' boilers is still fired by hand, and mechanical stokers have made very little progress in this field. They have been tried on a few passenger ships on the Great Lakes, but space limitations have been the determining factor in the type of stoker used. It has, therefore, been necessary to install types which conserve labor only to a very limited extent. Fires must still be cleaned by hand and coal must be shovelled from the bunkers to the stoker hoppers.

Some improvement is undoubtedly possible in the line of mechanical stokers which will ameliorate fire room conditions somewhat without turning to other fuels than lump coal. A more complete solution of the problem, however, lies in the use of fuel in liquid or powdered form.

Fuel Oil in Marine Service

Oil is the most convenient fuel for use on board ship. It can be pumped aboard through pipes and carried in the double bottom. It can be pumped to the burners and then blown into the furnace in atomized form, suspended in the air required for combustion.

It can be mined by drilling wells and then transported through pipe lines and tank steamers to refineries on the seaboard.

Our Petroleum Resources

If our petroleum resources were anywhere nearly comparable to our coal resources we could consider oil as the universal fuel for ships, as well as for many uses on land. The United States produces nearly two thirds of the world's supply of petroleum, but our production is largely consumed for purposes for which it can command a higher price than is permissible for competition with coal on shipboard.

Oil fields are not as well distributed for supplying ocean trade routes as are the coal fields. Oil must therefore be transported over greater distances than coal in supplying the majority of the world's seaports. But owing to its liquid form, it may be handled more economically than coal and, in many places, it can be piped from the wells to the seaboard.

For sources of oil which can be obtained at a sufficiently low price to enable this fuel to compete with coal in the merchant marine, we must look to Latin America, and particularly to Mexico, where low-grade oil is produced in quantity not far from the seacoast. Only a part of Mexico's oil, however, is of a low grade.

The demand for gasolene and other valuable petroleum products is increasing at a more rapid rate than the production of the crude oil. The natural sequel will be a steady increase in the price of gasolene which will, in turn, encourage the further application of the cracking processes for refining an increasing portion of the oil now burned as crude fuel in competition with coal. The introduction of steam and semi-Diesel motors, for commercial trucks and large passenger cars, will develop a new market for kerosene and fuel oil, and will supplement gasolene and gradually increase the price of these other products also.

This situation will also affect the better grades of oil to be produced in Mexico and South America. During the war, the production of oil in Mexico was held in check by the scarcity of tank steamers for exporting it.

The United States Shipping Board began its war program for steel ships on an oil-burning basis, but later modified this practice to the extent of making provision for burning coal as an alternative fuel owing to the increasing scarcity of oil. Fuel oil was a necessity in many of our war industries; also for our navy and for the navies of our allies.

The Shipping Board is now planning to base its whole steel-ship program on Mexican oil as fuel. The [illegible] make [illegible] carefully examine the [illegible] sources of oil, and the whole [illegible] American petroleum situation [illegible] in detail in future installments [illegible] of articles.

The data collected by the U. S. Geological Survey is sufficiently accurate to show that in this country more than one third of the original resources of petroleum have been exhausted and that there will be a gradual slowing down of production before [illegible] years have passed.*

The present annual production of petroleum in the United States is about 340,000,000 barrels of which 40 or 50 per cent is made into gasolene and other refined products. In 1915 we exported 55,000,000 barrels of crude oil and refined products.

The present annual production in Mexico is about 50,000,000 barrels, of which 36,000,000 are shipped to this country. The potential production of the Mexican oil fields is about 500,000,000 barrels annually, although the present pipe lines and river barges can transport only about 78,000,000 barrels to the seaboard.

In regard to the petroleum resources of Mexico, Gilbert & Pogue say:†

"It is not unreasonable to expect that further exploration and development will make available a reserve of oil in Mexico equal to the total remaining in the United States. Little in the way of petroleum imports may be expected from other parts of the world; South American needs will probably more than absorb the future output of that continent.

"At best, the deposits in Mexico, if fully available and barring international complications, would put off the period of petroleum exhaustion in the United States for only a matter of say a couple of decades. It would seem, so far as such things may be determined from the outside, that Mexico would take the lead among the Republics of Latin America in developing a policy in regard to petroleum development that would prevent production from exceeding the demand for the high-use products, as this legitimate drain may be expected largely to exhaust the supplies within a generation or two.

"On the whole, it would appear to be for the good of all concerned that the Mexican deposits should not be more wastefully exploited than those of the United States, for the world needs the full service of the aggregate supply."

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*See Part X of this series, "Our Future Petroleum Industry," by W. A. Williams, GENERAL ELECTRIC REVIEW, January, 1918.

†"Petroleum: A Resource Interpretation," by C. G. Gilbert and J. E. Pogue, Bulletin 102, Part 6, United States National Museum.

There are several factors which contribute considerable uncertainty as to the dependability of this source of oil. About 700 wells have been drilled in Mexico, but six of these have furnished three fourths of the oil produced by that country. The life of these phenomenal walls is difficult to predict. They may produce oil for a long time, or some of them may turn to water in a few years. One "gusher" got out of control when the drillers first struck oil. It caught fire and burned for 56 days, then suddenly turned to salt water.

The policy of the Mexican Government as regards the proposed taxation of oil lands to an extent which practically amounts to the confiscation of undeveloped lands, and the discouragement of further exploitation by foreigners, adds another factor of uncertainty.

Oil Consumption of Freight Steamers

An oil tanker of 10,000 tons dead weight capacity equipped with a 2500-h.p. geared turbine, burned 24,000 barrels of oil in five months during which time she steamed 32,880 miles at an average speed of 10.7 knots. She burned 1.03 lb. of oil per shaft, horse power hour. The United States Shipping Board is building fabricated steel cargo vessels of from 5000 to 10,000 tons dead weight capacity, but the present policy is to adopt the larger size as the standard for new construction. A 3000-h.p. geared turbine should drive these vessels at a speed of about 11.5 knots and will consume oil at the rate of about 1.03 lb. per shaft horsepower-hour, or 0.88 barrel per nautical mile. Allowing for the fuel burned while in port, we may assume, in round numbers, that these ships will consume at least one barrel of oil per nautical mile.

In the trans-Atlantic trade they will make about eight voyages per year, or 50,000 miles, and on longer routes they may spend more time at sea. One thousand of these ships will, therefore, consume at least 50,000,000 barrels of oil per year, and will represent 10,000,000 tons of shipping. Faster vessels in the passenger service will consume fuel at a higher rate. Our new merchant marine may require 80,000,000 or 100,000,000 barrels of oil annually.

The Navy Needs Petroleum

Many of the newer ships in the navy burn fuel oil. It is also to be used on all of the ships now building, as well as on those planned for future construction. The navy has more valid reasons for burning oil than the merchant marine, and our petroleum resources are inadequate to supply both services. Of the two, it will be easier to meet the requirements of the merchant marine with coal than the more exacting requirements of the navy.

Also, the navy cannot utilize powdered fuel until the industry is developed and coaling stations are equipped in many parts of the world. Then, naval vessels might use powdered coal as an auxiliary fuel and burn it under a few boilers at ordinary cruising speeds, when only about 20 per cent of full power is required. When full power is called for the remaining boilers will be fired with oil. Ships may be coaled at sea from colliers, through flexible hose, by means of the high-pressure air transport system.

Investigation of Alternative Fuels

It would, therefore, seem prudent that our government should begin the investigation of alternative fuels which can be utilized with the same economy of labor and with the same efficiency as oil.

There are several possibilities in the way of powered fuel:

1. Pulverized bituminous coal.
2. Pulverized semi-coke.
3. Granulated bituminous coal.
4. Granulated semi-coke.

The possible adaptability of pulverized coal for marine service has been recognized for some time. Pulverized coal has made considerable progress in the mineral and metallurgical industries, and it has been successfully applied to stationary boilers and locomotives.*

It has not, however, been applied to land boilers on a sufficient scale, as yet, to make an impressive showing, or to a sufficient variety of types to solve all the problems of furnace design that may arise.

It has not made as much progress in boiler firing as in industrial furnaces for the reason that the mechanical stoker had been perfected for boiler use before pulverized coal had a good start as an alternative fuel.

Where pulverized coal is prepared at the plant at which it is to be used, the problems of handling and storage have been successfully worked out. There is a field for more development work, however, in connection with the problems of storage and handling

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*See Part XVIII of this series, "The Extent of the Use of Pulverized Coal in the Industries," by F. P. Coffin, GENERAL ELECTRIC REVIEW, May, 1918. Also, Part V, "The Use of Pulverized Coal on Locomotives," by V. Z. Caracristi, November, 1917.

which will arise when the production of pulverized coal is centralized in large plants for distribution to consumers on land, and to ships.

Pulverized Coke

The application of powdered fuel in power plants and on ships might be considerably stimulated by centralized production, especially if the plant be equipped for carbonizing (i.e. partially coking) bituminous or lignitic coals at low temperature. In this process a portion of the volatile matter is distilled off for the recovery of by-products which can command a higher price for other purposes than as crude fuel.

The semi-coke produced can be pulverized and is better adapted to safe storage and handling than pulverized coal. The possible slight tendency to develop spontaneous combustion in storage (which some skeptical engineers base their objections upon) will then disappear. Also, the danger from explosive mixtures of coal dust and air will be rendered practically negligible. The cost of preparation should be offset by the returns from the sale of by-products.

Manufacture of Semi-coke

Many plants manufacturing gas for illumination and heating, at the present time, coke the coal in small retorts at a high temperature, and the cost of operation is high. Some of the low temperature processes offer possibilities for a simpler plant for large scale production.

Less gas will be produced per ton of coal for the reason that some of the volatile matter will be left in the coke, and this will result in a better coke for burning in pulverized form.

At least eight per cent of volatile matter will be left in the coke, or as much more as is necessary to obtain good combustion.

Anthracite and coke breeze, which contain but little volatile matter, have been successfully burned in pulverized form, but are more difficult to ignite. This difficulty has been overcome by appropriate furnace designs for burning low-volatile fuels. The processes in common use for making metallurgical coke and for the manufacture of illuminating gas produce hard coke that is expensive to pulverize. About 30 per cent more power is required for pulverizing a ton of metallurgical coke than for a ton of bituminous coal. Also, the capacity of the pul[illegible] about one-sixth owing to the [illegible] coke.

There are several processes for [illegible] at low temperature under [illegible] the present time in the United States [illegible] government is building a plant [illegible] western Virginia that will use one of these processes in order to obtain by-products [illegible] the manufacture of explosives.

In this process, also, some of the coke [illegible] be compressed, while at high temperature, into briquettes of artificial anthracite. This should be a useful fuel on small vessels where it will not pay to install mechanical firing systems. It can be fired by hand and will burn freely and without smoke. In regions where lignite, or other low-grade coals, are the only local fuels this will be especially useful.

Semi-coke can be produced from many low-grade bituminous coals and lignites, as the volatile impurities, including the combined moisture, are driven off and leave just as good coke for pulverizing as higher grades of coal. With the development of this industry it will be possible to utilize more sources of coal for bunkering ships.

Semi-coke contains all the ash in the original coal and it would, therefore, be desirable to clean the coal by washing or otherwise before coking. When even a high-grade coal is crushed and cleaned a considerable fraction of low-grade constituents may be removed. This fraction may be utilized at the preparation plant, in gas producers or in pulverized form, for firing the coke ovens or marketed for local use.

*"The percentage of by-products recovered from clean coal is greater than that recovered from highash coals; therefore the careful preparation of the raw coal by washing or other means is profitable."

Geographical Distribution of Coal Resources

The world's coal fields, which are accessible to tide water, do not all contain deposits of high-grade coal, such as is desirable for bunkering ships with a minimum encroachment upon cargo capacity.

The countries bordering the North Atlantic are exceptionally favored in this regard, and especially England where the distances from the mines to the seaports are short. For this reason the coal export trade has been one of the mainstays of the British merchant marine. Ships which bring food and raw materials to England carry return cargoes

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* "Carbocoal," by Charles T. Malcolmson, American Institute of Mining Engineers, September, 1918.

of coal at low freight rates to less favored countries in many parts of the world.

Good coal is produced from mines which are accessible to seaports in Natal, South Africa, in India, and in south Manchuria. The Matanuska field in southern Alaska is now being opened. There is, however, a much more extensive field of lignite located directly on tide water, on Cook Inlet in Southern Alaska. The Manchurian and Alaskan fields are the only ones containing high-grade coal which are accessible to the shores of the Pacific ocean. Canada and Australia have medium-grade coal near tide water on the Pacific; Washington state, Chili, Japan, and China have low-grade coal, and New Zealand and the East Indies have lignite. China has high-grade coal fields far inland, without railroad outlets as yet.

The countries bordering the Mediterranean and the South Atlantic have resources of lignite and low-grade coals but only a few localities where better coal is available.

Pulverizing Coal on Board Ship

At first it will only be possible to supply ships with powdered fuel on certain fixed routes, as in the trans-Atlantic trade. On trade routes where only lump coal is available, the advantages of pulverized coal firing can be obtained only by preparing the coal on board the ship.

The usual type of plant for drying the coal, and then pulverizing it in low-speed mills, is very cumbersome for installing on ships. A simpler type of high-speed pulverizer which can be coupled directly to a motor, and which does not require preliminary drying of the coal, might be used on ships. The multi-stage paddle type of pulverizer is often used without a preliminary dryer. A part of the air for combustion is circulated through the several stages in series, entraining the fine coal and carrying it to the burner in suspension. This pulverizer delivers the coal directly to an individual furnace without intermediate storage, and is used in some installations for firing rotary dryers, cement kilns, and lime kilns.

The paddle type of pulverizer does not always give a fine enough product for firing boilers, although it has given a fine product in certain tests. Possibly, if the coal and air were passed through a "cyclone" separator the coarse particles could be returned for regrinding, as is done in other types of mills, and a fine product obtained.

Granulated Coal

A new method was tried out in 1918 by Mr. A. M. Hunt for the United States Shipping Board. A pulverizer of the hammer-mill type was installed on a small coastwise freight steamer for granulating the coal to a product ranging from dust up to particles about one quarter inch across. This was delivered to a storage bin. It was drawn from the latter by suction and entrained with a small part of the combustion air, then blown into the furnace of a Scotch boiler above the grate, and without interference with the firing door.

A fire was first built on the grate with lump coal in the usual way. Then the "pneumatic stoker" was started and the dust content of the granulated coal burned in suspension like pulverized coal, while the coarse particles settled on the fire bed after being semi-coked by the radiant heat. This resulted in maintaining a free burning fire which formed much less clinker than usual and which was easier to clean by hand. Only a little hand trimming was required to maintain an even distribution of the coal. The furnace efficiency was found to be comparable to what could be expected with pulverized coal, and the dust content was sufficient to give an ability to raise steam rapidly, to meet sudden calls for power, while steaming slowly. In this respect, also, the flexibility was found to be comparable with oil or pulverized coal firing.

This method is also in successful use on a Niclausse marine water-tube boiler at the Naval Experiment Station at Annapolis, Md. For some types of marine boilers, including the Scotch boiler and possibly the A-type water-tube boiler, such as are used on many naval vessels, this method of firing granulated coal over a grate will undoubtedly give better results than pulverized coal. In the case of horizontal water-tube boilers, however, pulverized coal might be superior as it would eliminate the grate and the cleaning of the fire. However, the grate must be kept ready for installation in case reversion to hand firing becomes necessary. If the fuel is prepared on shore this will only be necessary when the vessel is diverted from her regular route and is unable to obtain pulverized coal. The change can be made in port when the furnace can be cooled. If the fuel is prepared on the vessel, however, and there is trouble with the apparatus for pulverizing or conveying, it must be possible to revert to hand firing without making any changes in the furnace. Also, if pulverized coal be prepared on the ship, it would be necessary to install spare apparatus to allow for occasional trouble.

A coal storage bin might be installed to tide over temporary shutdowns, but would introduce an additional element and render it necessary to separate the coal and air instead of carrying the fuel in suspension from the pulverizer directly to the furnace. Moreover, this would not provide for long shutdowns.

Most of the merchant vessels built before the war have Scotch boilers; also about one quarter of those built during or since the war. The water-tube boiler is superior in many ways; its weight is only about half that of the Scotch cylindrical boiler and it is more economical, requiring from 10 to 15 per cent less fuel. But many marine engineers are conservative and prefer some of the inherent qualities of the Scotch boiler, so it may survive in the merchant service for many years. In equipping Scotch boilers for burning pulverized coal it would probably be necessary to line the front end of the cylindrical furnace with firebrick, to form a combustion chamber, as hot refractories are necessary for reflecting the heat in order to obtain ignition and good combustion. This would blanket much of the most efficient heating surface in the boiler, and would also make it difficult to install a grate for reversion to hand firing. The removal of the ash and slag would also be difficult.

Therefore, where fuel is pulverized on the ship, granulated coal offers a better solution of the problem, as the ready convertability of the furnace to hand firing, without any changes, is an advantage even in the case of boilers for which pulverized coal is suitable.

The disadvantages of preparing the fuel on the ship are:

1. The weight and the space required for the pulverizer, and for the elevator which will be needed for delivering coal from the stokehold to the pulverizer.

2. The attention required for their operation and maintenance.

3. The coal must all be shovelled by hand from the bunkers, and transferred to the elevator, across the fireroom floor.

4. The ship must continue to be coaled in the old way with the accompanying dirt nuisance.

The last two objections apply to mechanical stokers also.

For freight [illegible] however, it might be [illegible] granulated coal on board and [illegible] would be particularly applicable [illegible] steamer. The hammer-mill [illegible] developed for the kind of [illegible] paddle type pulverizer may [illegible] For milling to a granulated product [illegible] only be necessary to reduce the number of stages as compared with the number [illegible] for pulverizing to a fine product. [illegible] machines are made in moderate sizes [illegible] for small installations.

Preparation of Fuel on Shore

For high powered vessels, however, it would be preferable to prepare the fuel on shore. Such vessels belong to regular lines and are usually operated on fixed routes. Smaller vessels operating over the same routes should be included. Granulated coal can be dried before grinding in order to minimize the tendency toward spontaneous combustion in storage and to facilitate handling. It would be necessary to so prepare it that the dust content will be sufficient to fill the voids between the coarse particles in order that it may not occupy excessive bunker space. Granulated coal can be handled by the same methods as pulverized coal and, if the coarse particles are not too large, the same equipment might be used which has been developed for handling the finer material.

Granulated Coke

What has been said in regard to the possibilities of pulverized coke applies equally to granulated coke. Semi-coke is very easily crushed but, in most varieties, when the cellular structure has been broken up and it has been reduced to solid particles, these appear to be harder and more difficult to pulverize than soft coal. One of the low-temperature processes, however, produces a semi-coke which resembles the original coal in its appearance as well as in its physical properties. This variety can be pulverized just as readily as bituminous coal. In any case it is easier to granulate material, with the production of a large proportion of dust, than it is to pulverize it all to the degree of fineness required for burning coal in suspension.

The hammer-mill is probably the most suitable type of pulverizer for granulating coal or coke on shore. Pulverized coal is prepared in several types of mills which were originally developed for grinding cement materials and these mills would also be suitable for pulverizing coke.

Where the fuel if prepared in central distributing plants, the relative ease of granulating rather than pulverizing is unimportant and only the use to which the fuel is to be put should be considered. Both granulated and pulverized fuel will be required as long as the Scotch boiler is used, and ships equipped with this boiler will require granulated fuel. Ships having water-tube boilers, however, can probably use pulverized fuel to better advantage. On shore, granulated fuel might be preferable in the case of small steam plants for heating, or other purposes, while pulverized fuel would be preferable for large power plants.

Burning Powdered Fuels

In burning pulverized coal it has usually been found advantageous to have a large furnace well lined with refractories to hold the heat and to radiate heat back to the cold incoming fuel. This promotes ignition and is especially necessary with low-volatile fuels. This principle is also used in furnaces where lump coal is burned on stokers. It is especially necessary for igniting low-grade coals. The coal should be blown into the furnace at a low velocity and given a long enough travel to allow the combustion to be completed before it reaches the boiler tubes. Pulverized coal is slower burning than oil or gas. On the other hand, the ash holds the heat and aids the attainment of complete combustion. This fact is more easily understood if we compare it with the burning of a correct mixture of gas and air in contact with incandescent solids, as in surface combustion, where complete combustion is readily attained.

Horizontal water-tube boilers, of the principal types now being installed by the United States Shipping Board, should be equipped with two large burners for pulverized coal, rather than a number of smaller burners, such as are used for fuel oil. They should be located not more than 2.5 feet from each side wall in order to heat the entire width of the furnace.

If burners are located too near the side, the wall may be eroded. The gases should not impinge on the refractory lining of the furnace until they have slowed down to a very low velocity, otherwise the particles of coal or ash will erode the wall if it be hot enough to be in a plastic condition. Some walls can be protected by a blanket of air admitted through an auxiliary opening.

Opposed Tuyeres

In firing certain small forging furnaces with pulverized coal, the wall opposite the burner has been eroded. This trouble has been overcome by admitting the secondary air for combustion through two tuyeres directly opposite one another and near enough for the blasts to impinge before losing velocity. The small blast of primary air carrying the coal is admitted in the center of one of the tuyeres. When warming up a cold furnace, a hot spot is visible where the blasts impinge. As the brickwork becomes heated this spot fades to a uniform glow which fills the whole interior. The introduction of coal on both sides has not given as good results.

Opposing flames have also been used in burning natural gas, but have not given good results with oil as the tendency is to cause smoke.

This method apparently has not yet been applied to the firing of boilers with pulverized coal, but it looks very attractive for boilers with small furnaces such as are used on board ship. The secondary air would be supplied by a low-pressure blower and piped to oppositely located tuyeres in the front and back of the furnace. The primary air, about one eighth of the total quantity, would be supplied by another blower under a few ounces pressure and delivered to a nozzle located in the center of the front tuyere. The pulverized coal would be carried in an intermediate storage bin, located above the fireroom and equipped with motor-driven feed screws at the bottom. The screws would deliver coal to the primary air pipe where it would become mixed with the air and carried in suspension to the burner. In entering the furnace the primary air jet flares out, owing to the eddies caused by the excess of its velocity over that of the secondary air, and the coal becomes mixed with all the air.

Opposed tuyeres should be particularly attractive for burning low-volatile fuels as the ignition would be accelerated by the mixing process, and it should be applicable with advantage to the burning of granulated fuel over a grate, especially with semi-coke. Where the two air currents impinge they lose velocity and this will give the coarser particles a good opportunity to settle on the firebed. At the same time, the fine particles will remain longer above the fire and subject to the influence of its radiant heat.

If the coarse particles can all be deposited in the front half of the furnace of a water-tube boiler, it might be possible to confine the grate to this area and allow ash and slag, from the fuel burned in suspension, to settle on the floor of the furnace in the rear. The grate could be sloped down from the firing door to the floor to facilitate removal of ashes from the rear. This will provide more space for burning the pulverized material where the height of the furnace is limited and will permit the use of fuel with a large content of fine material. Where there is sufficient height, arrangements can be made for dumping it into an ash pit.

The labor of cleaning grate fires might be largely eliminated by the use of shaking grates similar to those used in domestic heating furnaces. There are grates of this type on the market which are used in connection with hand-fired boilers. The grate bars are of various shapes and can be rocked for shaking the fire and dumping the ashes. The fact that large clinkers are not formed, and that the fuel is free burning, should facilitate the cleaning of the fire by this method. It will, however, be undesirable to introduce any more mechanical devices than are necessary as aids in burning powdered fuels, for it will detract from the simplicity of the furnace which is the attractive feature in burning pulverized coal or fuel oil.

Preheated Air

Preheated air is used in connection with many Scotch boilers on shipboard, but the temperature used is quite moderate. In the Howden system the air is heated to 200 or 250 deg. F. in some instances, in order to utilize part of the waste heat in the flue gas. When burning semi-coke, in either pulverized or granulated form, preheated air should be a great help in obtaining good ignition, and the hotter the better. There would be temperature limitations in the case of the primary air for carrying the coal, and for the underfire air which would pass through the grate in burning granulated fuel, but the overfire air could be heated to the practical limits set by the metal in a preheater working on the counter-flow principle.

Boilers might be operated at a higher rating and equipped with heaters of sufficient size to recover the excess heat in the flue gas. A little less boiler capacity would be required and this might compensate for the extra space, weight, and expense required for the air heaters.

Chemistry of Combustion

In burning pulverized coal under [illegible] tube boilers, with improper conditions of combustion, a sticky slag sometimes [illegible] on the tubes. This is often due to insufficient air, or to a poor mixture of air and coal, [illegible] results in a local excess of fuel. The following description of the chemical actions involved in the combustion of pulverized fuel is taken from a paper by J. E. Muhlfeld on "Pulverized Fuel for Locomotives."*

As a one-inch cube of coal exposes 6 square inches of area for absorbing oxygen and liberating heat, and when pulverized to the proper fineness will expose from 20 to 25 sq. ft. of area for oxidation, the first essential for complete combustion is the breaking up of the fuel into dry, minute, and uniform particles. Then by diffusing these so that each may be surrounded with the right quantity of air for complete combustion, it will be possible to burn practically all of the available combustible, regardless of the percentage of non-combustible.

Of the non-combustibles, ash contains a mechanical mixture of silica, alumina, iron, lime, potassium, sodium, and magnesium. The "clinkering" and "honey-combing" of ash is one of the worst troubles to be contended with in the combustion of coal, and its formation may be either chemical or by fusion.

Clinker is of two kinds, "hard" and "soft."

"Hard clinker" is formed by the direct melting of some of the ash content. It hardens as it forms and usually gives but little trouble.

"Soft clinker" is formed by the slagging of the ash and is either pasty or fluid, and steadily grows in size.

"Honeycomb" or "flue-sheet" clinker is formed by the condensation or coking of tarry matter or vapor as it strikes against the firebox sheets, and results in the accumulation of a relatively soft, light, ashy substance that grows or spreads over certain of the refractory or metal parts of the furnace.

With the use of pulverized fuel, the usual difficulties resulting from the formation of hard and soft clinker on grates are eliminated, but with fuels containing certain intrinsic combinations of ferrous silicates which fuse at comparatively low temperatures (2000 to 2300 deg. F.) the honeycomb formation will result, when the proper air supply and combustion do not obtain, to produce ferric silicates, which fuse at relatively high temperatures (2500 deg. F. and above). For

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*Journal of the American Society of Mechanical Engineers, December, 1916, p. 986.

example, during the process of combustion ferric sulphide (FeS_2), commonly known in fuel as iron pyrites, is reduced to ferrous sulphide (FeS) as the result of the chemical reduction illustrated by the following formula:

$$FeS_2 = FeS + S$$

As ferrous sulphide (FeS) melts at a comparatively low temperature (2138 deg. F.), it may surround itself with fuel and ash and form a pasty mass which may act as a binder to collect other ferrous sulphide (FeS), fuel, and ash, all of which may tend to collect on, and adhere to, the hottest parts of the firebox sheets, such as staybolt heads, flue heads, and like parts which are higher in temperature than the melting point of ferrous sulphide (FeS) and the surrounding metal surfaces, while the temperature of the latter may be lower than the melting point of the ferrous sulphide (FeS).

The following formula shows the result of incomplete combustion owing to insufficient air:

$$2\ FeS + 2O = 2\ FeO + 2S$$

By providing sufficient air through an excess supply, the following formula shows the result of complete combustion:

$$2\ FeS + 9O = Fe_2O_3 + 2\ SO_3$$

For this latter process an oxidizing atmosphere must at all times obtain in the firebox to prevent the reduction of ferric sulphide (FeS_2) to ferrous sulphide (FeS), as expressed in the first formula.

The ferrous sulphide (FeS), as has been shown, is the direct cause of honeycomb, for the reason that it produces ferrous oxide (FeO), which unites with the silica to form a honeycomb that is very fusible at temperatures over 2400 deg. F.; whereas by the production of ferric oxide (Fe_2O_3), in combination with the silica present, a highly infusible clinker is formed.

As a general rule an increase in the percentage of silica, alumina, and magnesium in the fuel matter will tend to decrease, while an increase in the percentage of iron, lime, potassium, and sodium in the fuel matter will tend to increase the fusibility of ash, but in every case a relatively high percentage of ferrous oxide (FeO), resulting from an insufficient supply of air for combustion, will be accompanied by honeycomb formation that will tend to adhere to various parts of the firebox.

Handling and Storage of Powdered Fuel

The handling and storage problems are vital to the success of any plan which involves the preparation of powdered fuel in central plants and its distribution to scattered customers.

High-pressure Air Transport System

Pulverized fuel can be readily handled by means of compressed air and blown through pipes. For short distances it can be carried in suspension in air, or handled by screw conveyors, but for longer distances it is more economical to use the high-pressure air transport system which blows it through a pipe in the form of alternate slugs of coal and air. This system has been installed in several industrial plants, within the last three years or so, for distributing pulverized coal from the preparation plant to bins located at the various furnaces. The coal is fed from the pulverizer to a pair of vertical cylindrical "blowing tanks." These are alternately filled and discharged into the pipe line by applying compressed air on top of the coal. The discharge pipes hang vertically from the top of each tank to within a few inches of the bottom. A larger curtain pipe surrounds the discharge pipe within the tank and is open at the top and bottom to allow the air to reach the open lower end of the discharge pipe where it helps to entrain and aerate the coal. The air forces the whole mass of coal slowly downward while it is being discharged upward through the pipe in the form of alternate slugs of coal and air, the air being supplied by the curtain pipe. A sort of pulsometer action takes place between the coal and air as they enter the discharge pipe. This is caused by the building up of static pressure until the coal slug reaches a length of about six feet. Then air cuts in beneath the coal and flows until the excess pressure is relieved. The coal is finally discharged from the top of the tank through a switch valve into the horizontal pipe.

Pulverized coal is being blown through four-inch pipes for various distances up to 1700 feet, using a maximum pressure of about 50 lb. per sq. in. at the start, and the rate of delivery is about four tons in five minutes. The maximum capacity of a four-inch transport line, served by a compressor with a piston displacement of 2000 cubic feet per minute, is about 50 tons of coal per hour for steady operation.

Dust resulting from the handling of pulverized coal is confined to the containers and piping, and the spent air is exhausted to the atmosphere through "cyclone" separators which recover the dust by centrifugal action. These are located in the receiving bin, or adjacent to a group of them. At the end of each blow, the residual compressed air in the tank is discharged through the line to clear it. The amount of dust escaping with the air is extremely small. Each receiving bin is connected to the transport line by a special switch valve which is operated either manually or by compressed air.

This system could be used for distributing either pulverized or granulated fuel for a limited radius from a preparation or storage plant. It could supply fuel to power stations and industrial plants; also to tank cars or barges for further distribution, and to ships at nearby docks. Barges will be required, however, for any general distribution to ships, or to shore plants located on navigable water.

Storage in Bulk

Pulverized coal will settle in a few days so that it will not flow readily. For getting it out of storage, when firmly packed, it must be re-aerated. This is done by installing compressed air pipes in the bottom of the bins, with air jets for fluffing up the coal. The pneumatic handling systems also help to loosen and aerate it during the process of discharging from the bin.

The behavior of coal, in this regard, is similar to that of other pulverized materials. Portland cement has been carried in bulk on a Great Lakes steamer and screw conveyors were installed in her bottom for discharging the cargo. At first it was found that the cement packed during the voyage and would not flow well to the conveyors, but would stand up in a nearly perpendicular wall. Compressed air piping was installed and air jets were used for fluffing up the cement. This treatment restored it to its original degree of fluidity by aeration.

These facts would seem to indicate that it will be perfectly practicable to prepare powdered fuel in centralized plants and to handle, ship, and distribute it with facility to scattered consumers. This is now being tried on a small scale in Seattle, Wash., where pulverized coal is being prepared at the mines of the Pacific Coast Coal Co., and distributed in tank wagons to the heating plants in some of the larger buildings. Granulated coke should be better adapted for distribution to small steam plants.

Powdered coke could be stored on land in large concrete bins which should be kept closed to exclude moisture. If [illegible] when first made the [illegible] will be unnecessary, and it should keep dry to make it readily handleable. The tank need not be absolutely tight, as it is necessary to exclude atmospheric moisture by admitting a very small stream of dry air at the top which will leak out through any opening in the tank. Compressed air can be used for this purpose as the excess moisture is condensed in the after-cooler of the compressor and drained off.

This method is also applicable to ships' bunkers, for ventilation and exclusion of moisture, and should be less expensive than making them absolutely air-tight. They should, however, be tight enough to prevent the escape of dust into the ship while coaling. Electric welding will be useful in making the joints. Where the bunkers are located along the sides, the ship's plating can be made thoroughly water-tight by electrically welding a fillet at the edges of the overlapping plates. This can be most readily done on the outside as the ship's frames would be in the way on the inside. With a few precautions there should be no difficulty from moisture.

Spontaneous Ignition

If pulverized coal be kept dry and cool in storage there should be no trouble from spontaneous ignition, as it has been kept in storage for a year or two without trouble. In other cases it has ignited after a few days storage, but usually in bins near a furnace. This ignition results in local coking, but combustion can proceed no further without oxygen, and this is very slow to diffuse through the mass of coal. The tendency to spontaneous ignition probably varies greatly with different coals and with the volatile content. A more definite knowledge of this matter is required and some large scale experiments would be desirable.

The possibility of spontaneous ignition or dust explosions could be further reduced by using compressed flue gas, instead of air, for filling and ventilating the bunkers and for fluffing up the packed coal. The flue gas contains only a little oxygen, but it should be cooled and washed with a water spray in order to prevent sulphuric acid and dust from entering the compressor.

Filling and Emptying the Bunkers

The simplest method for transferring the fuel from a barge alongside the vessel to the bunkers, would be to draw it out of the barge through a number of movable suction pipes, and to carry it in suspension in an air current to the bunkers. It can be syphoned out of storage by an ejector operated by air from a centrifugal compressor at pressures in the neighborhood of three pounds per square inch. This method has been successfully used for drawing granulated coal from a bin and blowing it into a boiler furnace. Syphon feeders of a similar type are also used for delivering pulverized coal to the burners of open-hearth steel and forging furnaces, high-pressure air being used as motive power. The air flotation system is extensively used for handling pulverized coal and other materials.

Substantial piping should be installed on the vessel and flexible hose may be used between the barge and the steamer. The barges would be similar to those used for oil, with a few bulkheads and dust-tight compartments. This system should be much cleaner in operation than the present methods of coaling.

The air and coal should be discharged into the bunker through a cyclone separator. The air should preferably be returned to the compressor, passing through a second separator if necessary, and used over again in a closed cycle. This will eliminate the possible escape of dust with the spent air. It will also render possible the use of flue gas in place of air, and the use of turbine-driven compressors installed on the ship. Many vessels have too small an electric plant to furnish motive power for fueling the ship. During the voyage, one of these compressors can furnish the motive power for the transfer of fuel from the bunkers to the intermediate bin over the boilers, by the same method. It will be preferable to keep this operation separate from the fuel feed to the burners as the latter operation requires accurate control of the coal and air.

Feeding the Burners

Pulverized coal can be burned with much less excess air than lump coal and, consequently, with better efficiency. Only 7 to 15 per cent excess air is required for smokeless combustion as against 50 to 125 per cent for coal burned on stokers or fired by hand. It is evident, therefore, that the coal in the intermediate bunker should be well aerated in order that it may feed readily to the screw and enable the fireman to control the proportion. In practice, it has been found easier to control the proportions of pulverized coal and air than is the case when burning oil.

Relative Fuel Efficiencies

Under good conditions, fuel oil can be burned under marine boilers with about 12 per cent better efficiency than hand fired coal; and an equally good efficiency may be expected of pulverized coal from results obtained with stationary boilers. Granulated coal, also, has given better efficiency than hand fired coal. As the available supply of stokehold labor is often of a low order of intelligence and skill, it is reasonable to expect that powdered fuels may be burned on shipboard with at least 20 per cent better efficiency than lump coal. When we consider the superior ability to maintain steam pressures, under adverse conditions and with poor coal, it is evident that the average thermal efficiency of the engine will also be higher.

Relative Bunker Capacities

The bunker space required for the storage of loose pulverized coal is greater than for lump coal, about 40 per cent more space being required for the same weight of coal. Assuming that pulverized coal may be burned with 20 per cent better efficiency than lump coal, the excess volume as compared with run-of-mine coal will be about 17 per cent.

Then there is the possibility of shaking down the pulverized coal when the bin is being filled. Pulverized coal when carried on the tender of a locomotive soon loses about one third of its original volume by the loss of included air. Condensing the coal might be accomplished by vibration produced by electrical or pneumatic means. The first 15 or 20 per cent reduction in volume may be accomplished very easily, and this will be sufficient to reduce the required volume to the same figure as is required for lump coal. There is a possibility of further reduction by vibration, but it would be more difficult to accomplish, and might make the fuel difficult to discharge. The air transfer systems and fluffing jets, however, break up coal even if very firmly packed. When fed into the zone of suction the air in the voids expands and releases the surface particles.

Pulverized semi-coke has about the same density as pulverized coal, and it can be shaken down to the same extent. In granulated form, even the spongy varieties will probably occupy less space. One of the processes under development gives a dense coke which can be readily pulverized. In either case the proportion of fine material should be sufficient to fill the voids between the coarser particles.

Semi-coke has a fairly high calorific value. If the ash content be about eight per cent, it should run about 13,300 B.t.u. per lb., or about the same as the average Pennsylvania bituminous coal.

The Present Bunkers May be Used

Except for making them dust-tight the present bunkers should be utilized with as few changes as possible, as they will be used for carrying lump coal when powdered fuel is not obtainable. When carrying powdered fuel, the openings for coaling and for withdrawing lump coal must be suitably sealed. Suction pipes for discharging powdered fuel should be made to swing through an arc in order to reduce the number required for withdrawing the bottom coal.

Where steam pipes pass through the bunkers they should be covered with heat insulation, and where pipes pierce the walls the joints should be made dust-tight.

Oil Cargoes in the Double Bottoms

The disadvantage of not being able to carry coal in the double bottoms, as is possible with fuel oil, may be offset in part by using this space on the outward trip for carrying oil as cargo which would otherwise be exported in tankers. This was done during the war, as an emergency measure when oil tankers were scarce. The shifting of the vessel to a different dock for discharging the oil was an inconvenience, however. This could be overcome by the use of oil barges, at the terminal ports, for loading and discharging the oil. This should be more economical than building extra tank steamers.

When carrying heavy mineral cargoes there is no advantage in utilizing the double bottom as the ship is loaded to the Plimsol mark before all the cargo space is filled.

Fuel Research Should be Done by the Bureau of Mines

During the war the United States Shipping Board has been carrying on several investigation in regard to the protection of ships against attack by submarines. In this connection Mr. Hudson Maxim* was authorized to prepare plans for an [illegible] in which the damage caused by a torpedo would be localized, as far as possible, by a barrier of steel cylinders used as bunkers carrying pulverized coal. The writer assisted in the preparation of plans for the [illegible] and the burning of this fuel under the ship's boilers.

Granulated coal was also tried out under Mr. Hunt's direction, in a preliminary way, as a means for maintaining the speed of the ships in a convoy and for the suppression of smoke. At present, the Shipping Board is confining its coal-burning investigation to the trial of mechanical stokers of commercial types. New methods for utilizing or conserving fuel are more properly the concern of other departments of the government. The Bureau of Mines has made careful tests of the principal types of boilers which are being installed by the Shipping Board, with fuel oil and with hand-fired coal, at their experiment station, in Pittsburgh.

The Bureau of Mines is the fuel research department of the government and has the organization to carry on experimental work. A new building has recently been completed in Pittsburgh for its fuel experiment station. It has the marine boilers for making full size tests of long duration, and pulverized coal can be obtained from some of the steel companies in Pittsburgh. Semi-coke can soon be obtained from the government plant in Virginia, or from private experimental plants. Officials of the Bureau have been desirous for some time of undertaking some experimental work in connection with the burning of powdered fuel under boilers, and as their equipment is being installed in the new building work can be directed in this channel as well as in any other if funds are made available.†

A Problem of Many Possibilities

The firing of boilers with powdered fuel is one of the vital points of attack on the problems of more efficiently utilizing our fuel resources. It opens many possibilities in utilizing low-grade fuels for power generation on land as well as on ships. Semi-coke should properly be considered as a low-grade fuel which can be most advantageously burned in powdered form or, in some cases, to make producer gas or water gas. Where it is made from high-grade coal for use on land, the

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*Chairman of the Committee on Ordnance and Explosives, of the Naval Consulting Board.

†The writer will be pleased to receive communications from interested readers which may be used as evidence of general interest in getting the proper authority from other departments of the government which will enable the Bureau of Mines to expend a portion of its available funds in making a start in this work. Later, the Bureau can make a recommendation that special appropriations be put at its disposal for continuing the work.

grade of the raw coal will be sacrificed for the sake of the more valuable by-products obtained. These include coal-gas, benzol, tar oils, ammonia, and pitch. The most important of these are the gas and the creosote oils. The use of gas for heating houses, and the use of creosote for wood preserving will be reviewed in detail in forthcoming installments of this series.

The general proposition of utilizing coal on a multiple product basis, rather than as raw fuel, has been reviewed.[*]

Need for Government Aid

Experimental work can be carried on much more expeditiously on land than on shipboard and, similarly, experiments in firing boilers with new fuels can be carried on to much better advantage in a laboratory than in a power station, where the boiler is needed for making steam. Most of the private experimental work, which has been done in this direction, has been subject to the limitations of old boilers which were installed for burning other fuels. There has been but limited opportunity to make changes in the boiler setting or to make a scientific study of the problems. The tendency has often been to try to "make it work" with as little time spent in experiments as possible.

Owners of power stations do not always look with favor upon the expense involved in extensive changes in the coal-handling machinery in existing stations, and it would be very desirable to have more data available to warrant the expense of putting powdered fuel in new stations. The companies in the pulverized coal business have rather small organizations and no facilities for carrying on experimental work on a large scale. The Bureau of Mines considers that there is a time in the early stages of an industry when the government can assist with constructive investigative work. This should be especially true in regard to the utilization of coal on a multiple product basis where many factors affect the possibilities of profitably marketing the by-products.[†]

"While any encroachment by the government upon what is popularly deemed the field of private industry may be looked at askance by the public; yet, if the nation's natural resources are to be conserved and the fullest possible benefit got from them, some authority having a wider vision than any single industrial concern, intent upon earning dividends, must exercise a certain degree of surveillance and afford a measure of constructive help in co-ordinating the ininnumerable features of industrial interrelationships. A constructive economic policy of this character is a true government function, and should insure rather than jeopardize legitimate gain by private enterprise."[‡]

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[*] "Competition in Coal Mining and Full Utilization of the Fuel," GENERAL ELECTRIC REVIEW, January, 1919, by Messrs. Gilbert & Pogue, of the United States National Museum, a Branch of the Smithsonian Institution.

[†] See Part XXV of this series of articles, "The Need for a Constructive Economic Policy for Upbuilding the Coal Products Industry," by Gilbert and Pogue, GENERAL ELECTRIC REVIEW, February, 1919.

[‡] From "Notes on Lignite; its Characteristics and Utilization," by S. N. Darling; Technical Paper 178, United States Bureau of Mines, 1918.

Welding as a Process in Ship Construction*

By Commander S. V. Goodall, R. N.

In discussing the matter of electric welding as applied to ship construction, the author [illegible] builder to shipbuilders, viewing the subject impartially from all angles, without extravagant [illegible] clusions being founded on a wide knowledge of the experience that has so far been obtained. [illegible] activity in the application of electric welding to ship construction is the outcome of a need to [illegible] of constructing hulls. Riveting is the greatest single labor item, and hence any improved [illegible] of binding together the hull structure offers the most fruitful field for economy. Electric welding [illegible] extent has been tried as a substitute and has been found successful. For a detailed treatment of [illegible] of electric welding we refer our readers to the December, 1918, issue of the REVIEW.—EDITOR

During the war economy of time in the production of all that was needed to terminate hostilities successfully was of paramount importance. Economy in first cost and maintenance was relatively unimportant. If the production of a ship, an airplane, a tank, or any implement of war could hasten the end by a single day it was more economical, in the long run, to place that implement on service today instead of tomorrow, even at a somewhat higher cost, for the shortening of the struggle by that single day meant a saving of many lives and millions of dollars. But besides being called upon to save time the engineer was forced to economize in labor and to use unskilled workmen. During the war gas welding and electric welding have been enormously developed as processes in the manufacture of munitions of all kinds. It goes without saying, therefore, that in these processes engineers found a means of saving time and labor.

Now that hostilities have ceased, economy in first cost and maintenance become once again of primary importance, economy of time and labor being of value only in so far as it results in cheaper production. This is particularly true of shipbuilding. Every shipbuilder should now carefully review the various items of cost in the production of a ship, and while he may devote his energies to a reduction all around, he will, if he be wise, give greatest attention to a reduction in the cost of the most expensive of those items. Riveting is this most expensive item. It has been estimated that the labor cost of riveting is about 40 per cent of the total labor cost of building the structure of a steel cargo carrier, while the labor cost of shopwork on structural material is about 15 to 20 per cent. During the past few years considerable attention has been given improvements in shopwork and it is unlikely that much economy can be effected in this direction. Can anything be done to lower the cost of riveting? The advocates of welding reply, "Yes, by a wide substitution of welding for riveting." This is a claim that should not be lightly placed on one side but carefully and critically examined by all shipbuilders. To offer some slight assistance in that examination this paper has been prepared.

Gas welding has been used in shipyards for many years, resulting in economy in the production of staple angles and similar smith work. It has found a wide field in the construction of light fittings, being more particularly of value for thin work than for heavy plating. As it may be considered that gas welding has now found its level as a shipbuilding process, this subject is not enlarged upon; the little that is said must not be taken as a measure of its importance.

Electric welding as a science and art has been dealt with at length in the technical press. As a process in shipbuilding much literature on the subject already exists, the most comprehensive papers known to the author being that by Mr. W. S. Abell, Chief Ship Surveyor of Lloyd's Register, read before the British Northeast Coast Institution of Shipbuilders and Engineers at Newcastle in November, 1918, and that by Mr. H. Jasper Cox, read before the Society of Naval Architects and Marine Engineers at Philadelphia in the same month. The author makes no attempt, even if he were capable of doing so, of giving such detailed particulars of the subject as can be found in these and other papers, but he does attempt to speak, as a shipbuilder to shipbuilders, plainly and impartially, without extravagant claims, and with some little knowledge of experience so far obtained, on the present position of the process and the policy which should be adopted, looking towards the future.

It is very well known that electric welding has been of great value on repair work, particularly during the war. Ships that would otherwise have been laid up for weeks while new castings were obtained, old plates removed and replaced by new, etc., have been

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* Presented at a joint meeting of the A.I.E.E. and A.S.M.E., New York City, February, 1919.

rapidly repaired and returned to service. If the ship repairer finds a process of such value, the shipbuilder should at least inquire whether it would not be of some value to him.

The Classification Societies have sanctioned the use of electric welding for a considerable amount of work of little importance so far as structural strength is concerned. The Welding Committee of the Emergency Fleet Corporation has found by actual experience that a labor saving of at least 60 per cent results from the substitution of arc welding for riveting on these minor parts of a ship; and Mr. J. H. Anderton has estimated that a saving in time of 70 per cent was effected at Hog Island.

Lloyd's Register of Shipping is prepared to classify an electrically welded vessel, subject to the notations, "experimental" and "electrically welded," and provided the builders conform with certain rules. This decision was reached after an extensive and exhaustive series of trials. Before any electric welding system can be employed on a vessel which Lloyd's will classify, specimens welded according to that system must satisfy tests, which, at first sight, appear almost prohibitive in their severity, but an electrically welded ship is now under construction at Cammell Laird's, England, to be classified by Lloyd's, who have approved the employment of the Quasi-Arc Company's system in its construction. This is a small vessel about 150 feet long, with plating generally $\frac{3}{8}$ to $\frac{1}{2}$ in. in thickness.

Electric welding work carried out by the British Admiralty has been described in a paper read by the author before the Engineers' Club of Philadelphia, in July 1918. Since that time valuable experience with this work on service has been obtained. The arc welded barge has been satisfactory. The cost of material, electric current, and labor for this vessel was £301 as compared with £389 5s. 0d. for the cost of riveting, calking, and drilling on a similar barge constructed at the same yard. The vessel was designed to be rivetless as a demonstration of arc welding, but it was found that greater economy would result if certain parts such as beams to frames, floor plates to angles, etc., were riveted.

As the plating of this barge is thin and stresses to which it is subjected are not comparable to those which a large seagoing ship is called upon to withstand, greater interest attached to experience with other British ships in which arc welding has been employed by the Admiralty, particularly to those where the work has been comparatively heavy. It must be said at once that failures of welded joints have been reported, although the number of such failures has not been large considering the amount of work that has been done, the lack of experience, the dearth of skilled operators, and the radical change in method. The admiralty authorities, however, consider it wise, pending further experience, to defer the adoption of electric welding for those parts of the structure subjected to high complex stresses, unless the work can be so tested as to demonstrate exactly that such stresses can be safely carried.

Lap welding has been more satisfactory than butt welding, and the latter has been, for the present, discarded for all important work where the plating is $\frac{3}{8}$ in. or more in thickness. It is hoped that this situation will not last long, for it is in butt welding that the greatest gain from the use of this process may be expected, and lap joints necessitate a certain amount of overhead welding which is difficult and unreliable.

While the above briefly sums up the present position of electric welding as a process in shipbuilding, it may be fairly asked why, if the Classification Societies permit the process on minor parts, if Lloyd's are prepared, subject to certain conditions, to classify an electrically welded ship, if the British Admiralty has employed the process to a considerable extent, if the American railroads have used welding extensively on locomotives—why has not electric welding been adopted in American shipyards to a greater extent than it has been up to the present? There is no doubt that, during the war, shipbuilders in the United States were too hard pressed to be able to give much time and thought to the development of an entirely new process in ship construction. This is one reason. Inate conservation is another. But the real reason, in the other's opinion, is that shipbuilders know that, at present, welds are lacking in uniformity, and it is not yet possible to tell when the welded joint is good or bad. Hence they hang back and the author commends their wisdom. It is far better that the first ocean-going electrically welded ship should be on service three years hence with every joint sufficiently sound—universally accepted as a thorough success—than that it should be at the bottom of the sea tomorrow because, while 999 joints were sound, one went astray.

How can this certainty that every joint will be efficient be ensured? While the electrical engineer and the metallurgist can assist the shipbuilder to solve this problem, there is much that he himself can do.

In the first place he must realize the importance of employing only thoroughly skilled and experienced workmen, and he should call in the manufacturers of electric welding apparatus to assist him. The latter, for their own protection and the welfare of the industry on which they rely, should see to it that no ship should be allowed to be built with some of the thoroughly rotten work done by absolutely unskilled welders that the author has seen. It is strongly urged that steps should be taken at once to establish welding as a skilled trade and only certified men should be allowed to be employed. All the reports that have been seen on good and bad welds lay stress upon the fact that, in general, defects are mechanical and not an inherent feature of the process. Skilled men working under an experienced foreman would know, for example, that clean surfaces are necessary for good work, they would quickly learn what types of joint are made with ease, in what portions of a ship welding is cheap or where it is unreliable; and from their ranks should be drawn the draughtsmen who will design in detail the welded vessel of the future. The Electric Welding Committee of the Emergency Fleet Corporation has spent much time and thought on the attempt to discover a practicable non-destructive method of testing welds. While such a method of testing would be very valuable, it is the author's opinion that when only welders of proven skill are employed under experienced supervision, such tests would be no more necessary than a shear test on every rivet of a riveted ship; but, so long as such welders are not available the shipbuilder will look askance at a process that may be good generally but may have weak spots of which he is ignorant.

Secondly, after he has trained a reliable staff of welders on work of minor importance, the shipbuilder must devote his attention to the best method of assembly of large parts, so that he may feel reasonably sure that every joint of the finished structure possesses the qualities which his welders can with certainty produce in test pieces. From the very outset it has been realized that this is a difficult problem which can be solved only by patient trial and experience. Present opinion at the British Admiralty is that the only satisfactory method is by the use of closing bolts as for riveted joints. [illegible] Richborough barges a certain [illegible] buckling resulted on the outboard [illegible] the garboard strakes after the [illegible] had been welded to the keel plate, but [illegible] removed when the bilge plates were [illegible] position and bolted up. In the heaviest [illegible] it may be that, buckling of plates being impossible, the internal stresses set up by welding were the cause of the failure that occurred. It is understood that this method is being adopted at Cammell Laird's, but again the plating of this vessel is not very heavy and it is definitely known that this feature received most careful consideration from the very beginning. In the author's opinion this difficulty is by no means insuperable. Its existence should spur on the progressive shipbuilder, for when he has solved the problem, by that much will he be ahead of his competitors.

In the third place it appears to be the fact that shipbuilding steel in Great Britain is more adapted to welding than shipbuilding steel in this country, and the former is also more regular in its qualities. If shipbuilders are satisfied that such is the case and are also convinced that electric welding has a great future in ship construction, they should take concerted action to ensure that steel producers supply the material best suited to their purpose.

So far the author has urged a careful survey of the possibilities of welding as a substitute for riveting only on the ground that the latter is the most costly item of labor on structural work, and it behooves the shipbuilder to reduce that cost. But there are other advantages incidental to welding that must not be overlooked. A sound arc-welded joint is necessarily watertight and once such a joint with known efficiency can be made with certainty calking is eliminated and the work of water-testing made easier. It must be admitted that, so far, the advantages anticipated in this direction have not been fully realized, but that they will be realized is only a matter of time, and it has already been fully demonstrated that welded joints, being stiffer, stand up better under test, and there is no breaking away of the caulk such as is sometimes experienced with riveted connections under water pressure. Another advantage is a saving in steel due to the absence of rivet heads and the smaller width of lamps and butt straps. Some advocates of welding claim that the labor of marking off, punching, and assembling will be much reduced, more particularly by the adoption of spot-welding; but the author is bound to say that at present he is not a convert to the adoption of spot-welding for heavy ship work. It is his opinion that there are many difficulties ahead of those shipbuilders who attempt this form of welding, and until these difficulties have been fairly and squarely met he hesitates to affirm that spot-welding will be found a valuable process in ship construction.

In conclusion it is desired once again to place the subject before the shipbuilder in this light. The cost of ship construction must be reduced. A reduction in riveting is the most fruitful field for economy. Electric welding as a substitute has been tried to a limited extent and found successful. Classification societies are prepared to accept the process, though at present the only vessels built or under construction are small. There are difficulties ahead but they do not appear insuperable. The best line of approach appears to be to build up a staff of thoroughly skilled welders, to gain experience by the adoption of welding on minor parts, to proceed cautiously in the extension of the process to more important members, not to expect a great saving in time and cost immediately, but to persevere, not necessarily towards the rivetless ship, but towards a vessel in which the employment of both processes of riveting and welding is so adjusted that more riveting or more welding could only be done at greater cost.

IN MEMORIAM

Herbert C. Wirt, an old employee of the General Electric Company, late of the Sprague organization, died suddenly on January 15th, at the Hahnemann Hospital, New York City, following an operation for appendicitis.

H. C. WIRT

Mr. Wirt was born in 1867 and first entered the employ of the General Electric Company at Boston in 1893. In 1894 he was transferred to Schenectady, N. Y., as Engineer of the Supply Department. In this capacity Mr. Wirt was very ingenious and accomplished many important improvements in design and method of manufacture, as applied to wiring supply devices.

In May, 1906, Mr. Wirt resigned from the General Electric Company, and with a number of New England capitalists, formed the Wirt Electric Company with a factory at Burrage, Mass. The venture, however, did not prove entirely successful, and in 1914 Mr. Wirt reentered the employ of the General Electric Company at its Sprague Works, where he was associated with the Switchboard and Panelboard Department at the time of his death.

Mr. Wirt was twice married. His first wife, Emily Loring, who died some seven or eight years ago, was the daughter of the renowned shipbuilder, Harrison Loring, of Boston. Mr. Wirt is survived by his second wife, Louisa B. Wirt, whom he married in 1913, and four children by his first wife: a daughter, Margaret B. Wirt, a student at Smith College, and three sons, Lieut. Harrison Loring Wirt, now with the Engineers of the A.E.F. in France, Sydney Hedges Wirt, of Boston, and Herbert C. Wirt, Jr., in school at Fesenden, Mass.