MADDOX

Tests of Household Electrical Appliances

Electrical Engineering

M. S.

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TESTS OF HOUSEHOLD ELECTRICAL APPLIANCES

BY

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B. S. University of Illinois, 1907

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

MASTER OF SCIENCE

IN ELECTRICAL ENGINEERING

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1909

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WILBUR CLINTON MADDOX

ENTITLED TESTS OF HOUSEHOLD ELECTRICAL APPLIANCES

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

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Introduction

Ever since civilization began men have been trying to make living more enjoyable by taking away the drudgery connected with it and making their commonest tasks, instead of disagreeable burdens the means of real enjoyment. It is for this fundamental reason that practically all of the useful inventions have been made. To-day life is far different than it used to be because these inventions have taken a place in our civilization, and we may be sure that it would hardly be desirable to change the new for the old.

The home is as it always has been, the most important part of our everyday life; so it seems justifiable that there, if anywhere, we should strive to take away drudgery and substitute enjoyment. Coupling with this idea the new born faith of our era in the possibilities of making electricity serve us better than any power we know of, modern engineers have taken up the problem of making electricity the servant of the home. For a long time we have used it there for light, but for little else. It is the object of this thesis to describe many new ways that are both convenient and economical in which electricity may be used in the home.

THEORY OF HEATING

Heating of a conductor

Since when electric energy is dissipated in a conductor the only resultant energy noticed is heat, it is generally assumed that all of the energy of the electric current is transformed into heat. In a sense this perhaps is true. The I^2R loss in a conductor is perhaps purely a heat loss, that is, all of the energy of the electric current may be used up in heating the molecules composing the conductor, but if this is the case it is also true that not all of this heat of the molecules can be taken from them in the form of heat except in certain special cases. One of these special cases is where the conductor is placed in a water bath. Since the water calorimeter is the common method of measuring the efficiency of heating apparatus, and since it is the method always used in measuring the heating efficiency of electrical heating apparatus, it is assumed that the electrical heating apparatus always shows 100% efficiency. Because this belief is so strong scientific men have devoted practically none of their time to the consideration of the efficiency of electrical heating apparatus.

I^2R loss

Water Calorimeter

Bunsen burner as an Air heater

It is a well known fact that a Bunsen burner burning free in a room will not materially affect the temperature of the room, while the same burner if placed inside a stove pipe will raise the temperature of the room considerably. Several gas companies, recognizing this fact, have been able to construct gas radiators

showing rather high efficiency. If we assume that when a certain amount of gas is burned a definite amount of heat energy will be produced, we must ask ourselves what becomes of all of the heat of the Bunsen burner when burning free in the air of the room. It has been suggested that this heat is used in heating a small quantity of air to a very high temperature, which quantity of air ascends to the top of the room, and its heat is thus not noticed. While this is true to a certain extent,the heat thus accounted for is found to represent only a small proportion of the energy generated by the burning of the gas.

Energy required to heat a room

For the purpose of our discussion we will consider a room about eight feet square and containing about 500 cu. ft. of air. Regnault gives the mean value of the specific heat of air at constant pressure between 0° and 100° C. as 0.2374. The weight of a cubic foot of a mixture of air and vapor such as is found in the average room at 20° C. is 453.59 grams. Hence we find that the total weight of the air of the room is 17000 grams or 37.5 pounds. The heat required to raise the temperature of this air 1° C. is then 17000 X 0.2374 = 3938.25 therms. Where a therm is taken as the quantity of heat required to raise the temperature of one gram of water 1° C. The amount of energy which crresponds to one therm is known as the mechanical equivalent of heat, and is found by experiment to be 42 X 10^6 ergs.

The unit of force is taken as that unit which is capable of producing an acceleration of one centimeter per second per second in a mass of one gram and is called the dyne. The erg is the unit of work which is done when a body is acted on by a force of one dyne through a distance of one centimeter in the direction of the force. One watt-sec. = 10^7 ergs, and since a therm = 42 X 10^6 ergs, it can easily be shown that one therm is equal to 4.2 Watt-sec. or one watt-sec. = .238 therms, and one watt-hour = 587.1 therms or one kilowatt-hour = 857 calories, one calorie being 1000 therms. Therefore the total watt-hours required to raise the temperature of the room 1°C. $= \frac{3938.25}{857.1}$ = 4.59 watt-hours. Of course this is taking no account of the heat which must be absorbed by the walls and fixtures of the room. It is also a fact that the air in the average room is continually changing, the walls being more or less porous and by no means air tight. Assumming that it is desired to raise the temperature of the room 10° C., it will require 10 X 4.593 or 45.93 watt-hours. If it is desired to raise the temperature of the room 10° in 20 minutes, which is about the average service required of an electric radiator used in a bath room or some similar place simply as an auxiliary heater to raise the temperature of the room quickly when perhaps the regular heating system is not in operation, it will require 3 X 45.93 or 175.7 watts. Since we have t aken the specific heat of the air at constant pressure we have already accounted for a great deal

of the heat of the air which may have escaped through the walls of the room. If now we assume that as much heat is absorbed by the walls and fixtures of the room as is used in heating the air we find that a radiator of 275 watts capacity should be sufficient. This statement to persons familiar with electric heaters seem absurdly low.

Energy wasted in the form of Ether waves

The low efficiency of the Bunsen burner when used as an air heater may be accounted for by the fact that energy is lost from the flame in the form of radiations which are either not absorbed by the air and the fixtures of the room or if they are their energy is transformed into something different than heat. As a suggestion it may be electrical energy. All gas flames are known to be sensitive to the electric oscillations used in wireless telegraphy and telephony, and hot electric rheostats may be made to give off high frequency oscillations or waves. The emission of this form of energy almost entirely disappears when the rheostat is placed in water, and for this reason electric water heaters may be made to show an efficiency of 100%. This is partly due to the absorption power of water for electromagnetic waves, but it seems to be more largely due to the fact that water is a conductor of heat, and it appears that a body constructed of a conducting material the outside layer of which is sufficiently cooled below the temperature of the inside by conduction, will not

emit electro-magnetic waves to any very great extent.

Thermal Radiations

The majority of artificial scources of light and heat are found to give off radiations which are similar to light and yet are able to traverse not only air but also metals and a great number of bodies which are opaque to the radiations of light. These radiations are essentially electro-magnetic radiations. In every case they may be absorbed and transformed into heat by coming into contact with certain substances. We here make the distinction between thermal radiations and heat. The two are readily changed from one into the other and yet are apparently as different from each other as current electricity is from light. Heat is a subtle form of energy, which, in many ways, is next to impossible to control or regulate, due to the fact that it cannot be insulated to any degree of satisfaction, and even if one has it in such a position that it seems to be well insulated, it, like the fairies of old, has the power to change its form and vanish into something thinner than thin air as it were. It, like current electricity, may be conducted through metals to a certain extent. Those metals which offer the path of least resistance to the flow of electricity also offer least resistance to the flow of heat. Thermal radiations, like electric radiations, are apparently waves in the ether. In fact, light, thermal, and electric radiations may all be classed under the head of electro-magnetic waves and differ

Heat

from each other as regards wave length.

Ether

The medium for the propagation of light is termed ether. Since ether pervades not only terestial but also interstellar space, it cannot be identical with our atmosphere. We must assume that ether pervades all transparent bodies. Since the behavior of light in material bodies is different from its behavior in the simple ether we must assume that the presence of matter modifies the properties of the ether. These properties are evidently determined by certain unknown actions tetween the material particles of the body and the ether pervading that body, and thus differ for different bodies. Consequently we may conceive of ether as pervading even opaque badies as well as all space; that is, it may be regarded as a continuous media.

Wave length

Waves in the simple ether travel with a velocity of 186,000 miles per second, and the length of these waves varies from the short wave length of light of the dimention of thousandths of millimeters, to the length of the electric wave proper which is expressed in meters.

Heat
Light
Electricity

When the length of the electro-magnetic wave falls within certain limits these waves are capable of affecting us through certain of our senses. For example if the length has any value between 0.43 and 0.75 u, where u = .001 millimeters, the waves affect the retina of the eye and we experience the sensation of light, the exact

wave length determining the color. In like manner waves having a length of from 0.5 u to waves of one or two millimeters in length produce a sensation of heat when falling upon the skin. These waves are designated as thermal radiations, and it is with these that we are principally interested.

Energy received from the sun

In diagram I is given a sort of classification of the electro-magnetic waves received from the sun. In this classification thermal radiations are taken to include only those radiations which are readily absorbed and transformed into heat when coming into contact with most of the common substances. The actinic radiations are those which have the power to blacken silver chloride and silver bromide. Even as these are not the only radiations which are chemically active, the thermal radiations here shown are not the only radiations which are capable of producing heat. In the same way that luminous radiations are absorbed to a certain extent by all substances thermal radiations are also absorbed to a certain extent by all substances. For example glass does not absorb luminous radiations as readily as most substances, but light will not pass through it without loosing some of its energy. All radiations of the shorter wave length will pass through glass with only a slight absorption, the absorption being apparently about proportional to the wave length. Incandescent bodies such as the sun and the electric arc appear not

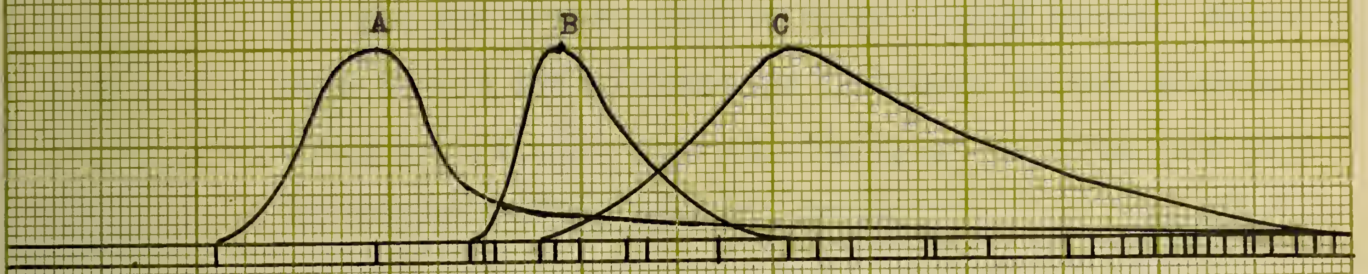


Diagram I

A Thermal radiations

B Light radiations

C Actinic radiations

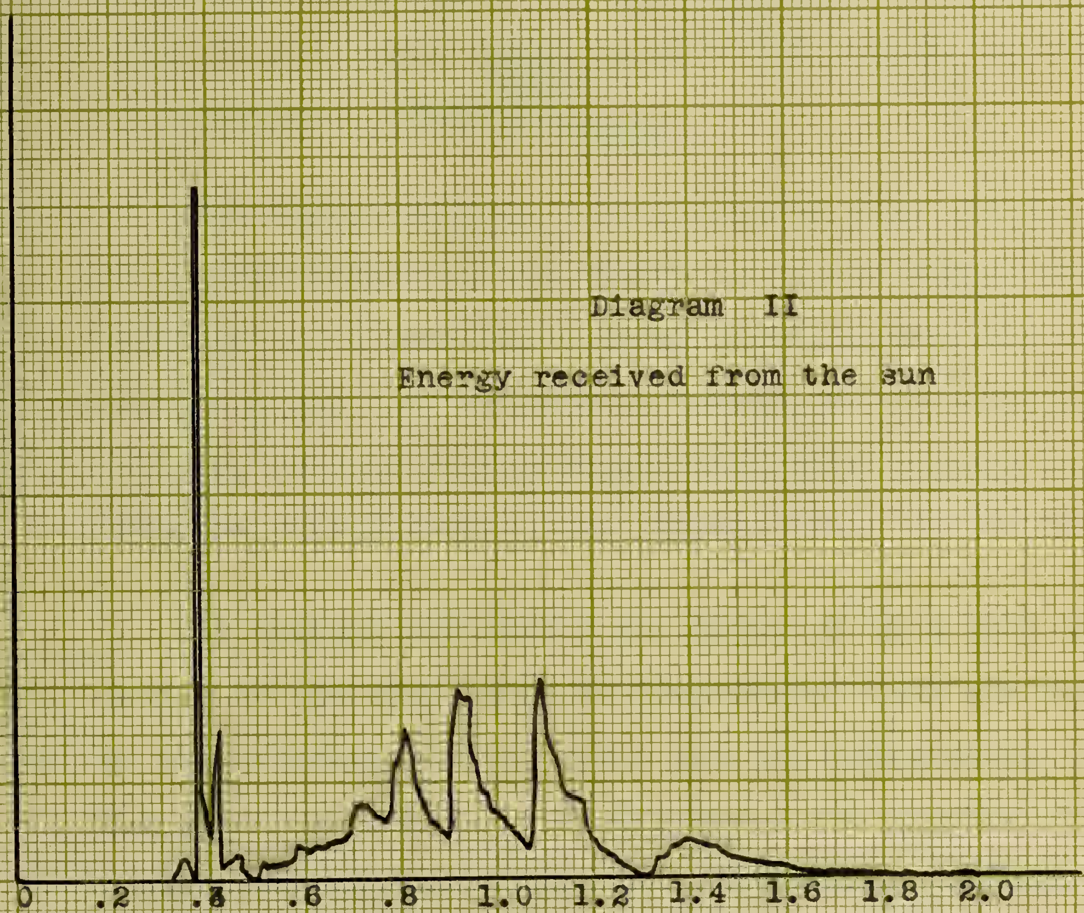


Diagram II

Energy received from the sun

to give off waves of a greater wave length than about 1.5 u, while colder bodies give off waves of considerably greater wave length, and it is found that most substances are transparent to these longer waves. Waves of more than a few millimeters in length do not produce a sensation of heat when falling upon the skin, and may be classed purely electric waves.

Absolute Zero

Hot bodies are not the only ones which emit thermal radiations. In fact it has been shown that these radiations may also be emitted from such bodies as ice or even colder bodies. At absolute zero which is at -273° C. all bodies cease to give off thermal radiations or vibrations.

Temperature

The temperature of a body depends upon the rapidity of the vibrations of the molecules of the body. The molecules of a body which is at absolute zero are at rest, and the only difference between a hot body and a cold one is that in the former the molecules are in more rapid vibration than in the latter.

Absorption of thermal radiations

If thermal radiations are absorbed by a body the energy of the radiations is transformed into the energy of the molecules of the body, and the temperature of the body is thus raised. All substances are capable of absorbing thermal radiations of certain wave lengths, and most substances are also transparent to certain radiations. Rock salt is found to be almost perfectly trans-

parent to thermal radiations, while crystalline alum is very opaque. Water is perhaps the most opaque of all substances. All substances emit radiations of certain definite wave lengths, and all substances are opaque to the certain radiations which they emit. Thus, the radiations from a certain piece of iron are of certain definite wave lengths, and will not pass through another of similar iron, but will be absorbed by it, and their energy transformed into the energy of the second piece of iron. Since all bodies which are above absolute zero in temperature emit thermal radiations, and since by so doing they loose molecular energy and are thus cooled, it would at first thought seem possible to have a cold body surrounded by warmer bodies and at the same time growing colder, assuming that it received no heat from the surrounding objects. Since the cold body does not grow colder, but on the contrary, will in every case become warmer, it is evident that it must absorb radiations faster than it emits them. The absorption of radiations is inversely proportional to the absolute temperature.

All substances are opaque to the radiation which they emit

Thermal radiations have the same characteristics as light radiations. Like the latter they are transmitted in straight lines from their source, and are reflected from certain surfaces and absorbed by other surfaces. The power of a surface to emit thermal radiations is always equal to the power which that surface

has for absorbing thermal radiations. As the temperature of a body is increased the radiations, set up in the ether surrounding the body by these vibrations, are also increased in frequency and become of shorter wave length until at last the wave lengths of light are produced. The red waves, being of shorter wave length, are reached first, and the body is then said to be red hot. The shorter the wave length the more readily are the radiations absorbed. The long electric waves pass freely through most substances, while the waves of light will pass through only a certain few substances commonly called transparent. All transverse waves in the ether are accompanied by magnetic or secondary waves, which in the case of heat transmission may represent a considerable loss of energy. The energy of these secondary waves increases very rapidly with the increase in the length of the primary waves, and for very short waves becomes an almost infinitesimal quantity. For this reason, and also because of the fact that most substances are opaque to the radiations of short wave length, it can readily be seen that a radiator with an element operating at a high temperature will give a higher efficiency than one operating at a low temperature, providing that we desire to heat our room by radiation and not by conduction or convection. If the latter method of heating is used a rather high efficiency may be obtained provided a sufficient quantity of air is brought into contact with the heating element. Cool air, on coming into contact with

Absorption power of surfaces

Conduction and Convection

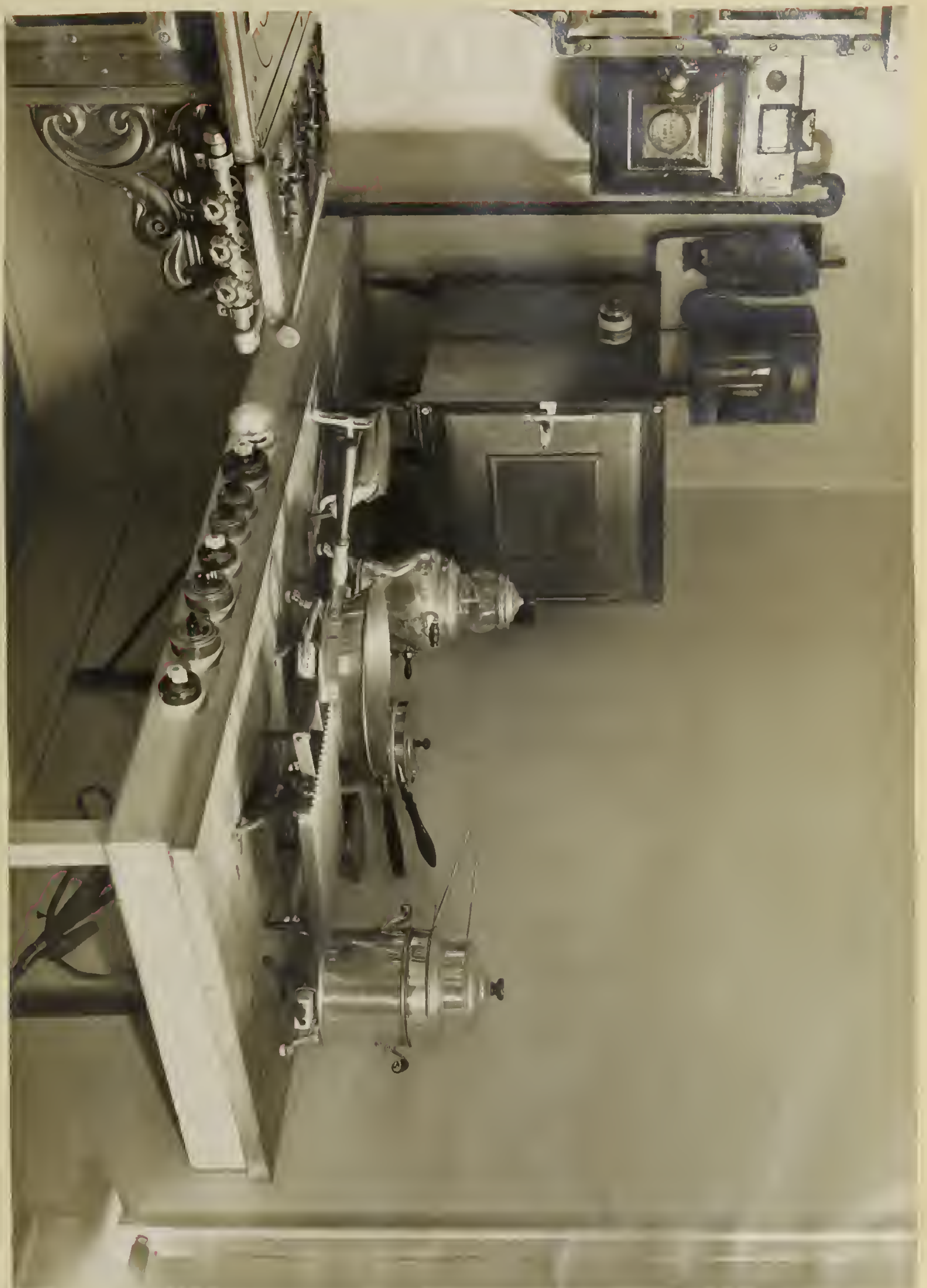
the molecules of the hot body, will extract a great deal of their heat by conduction, if a sufficient quantity of air is brought into contact with the heating element. Cool air, on coming into contact with the molecules of the hot body, will extract a great deal of their heat by conduction, and if sufficient quantities of air are made to pass over the surface of the radiator the thermal radiations will be greatly reduced. This principal is made use of in the electric hair driers in which a very small electric heater is made to heat large volumes of air. This is by far the most economical form of air heater on the market at the present time. The radiant or glowing heat received from a fireplace of glowing coals is very marked. A blazing fire, while perhaps consuming more energy, may not appear to give off as much heat. For heaters from which it is desired to receive heat not by conduction or convection but by radiation, the problem resolves itself into the construction of a heating element which may be worked in the open air at a glowing heat.

Electric Hair Driers

Thermal Spectrum

While it is true that the air and fixtures of a room absorb the waves of short wave length more readily than those of the longer wave length, it is also true that there are a great many of the shorter waves which are not absorbed, and hence throughout the spectrum of thermal radiations we have absorption bands similar to those found in the visible spectrum of light. For this

reason the waves from certain glowing radiators now on the market are not readily absorbed and these radiators also show low efficiency. In the judgement of the writer, if solid bars could be made of some substance having the same general characteristics as cryptol and which would not oxidize in the air at high temperatures they would make good elements for electric radiators. Aluminum bronze is a substance which will not oxidize in the air at high temperatures, but this gives off more of the undesirable radiations than does cryptol.



Cooking Apparatus

Cooking Apparatus

Efficiency of gas stoves

In taking up the subject of cooking apparatus we will begin as in the case of radiators, with a short discussion of gas appliances. The average burner on the best gas range is found to give a heating efficiency of not better than 15%. With the idea of perhaps improving on this efficiency, a stove was built in which the gas flame was entirely enclosed in a metal combus-

New design of stove

tion chamber. The sides and bottom of this chamber were lined with a refractory material, and the top was made of brass on which cooking could be done the same as on an electric hot plate. The products of combustion were carried away through a pipe to a flue, thus doing away with all of the undesirable products of combustion in the room. This stove was similar in appearance to some of the electric stoves, and apparently had most of the advantages of the latter, being perfectly clean and free from all soot. This stove, while perhaps built on correct principles, was not found to give the results expected of it, due to faults in design which could undoubtedly be overcome, if sufficient time and thought were devoted to the question.

Advantages of gas as a fuel

While the cost of one heat unit in the form of artificial gas is of necessity considerably greater than the cost of one heat unit in the form of coal, yet the greater saving brought about by the direct application of the gas flame and the fact that it is possi-

ble to entirely shut off the supply of heat when not needed make it possible for the low efficiency gas appliances now on the market to show in many cases even a saving in cost of operation over the other methods of cooking.

Coal as a fuel for cooking

It is very hard to estimate the efficiency of a coal range. It depends on the proportion of the time that the range is being used to its full capacity. At the best the efficiency is very much lower than in almost any other form of heat engine, and in the case of small families where the cooking is very light, the cooking efficiency is so low as to make this one of the expensive methods of cooking, while where a great deal of cooking is done, it is perhaps by far the cheapest.

Electric Oven

In the case of the electric oven we have a proposition to deal with very similar in many ways to the air heaters or radiators considered in the previous chapter. Here the radiator is used to heat a small quantity of air to a very high temperature. In many electric ovens, the heaters are incased in iron or some similar metal, and the walls are made of sheet iron which very readily absorbs the radiations from the heater and become very hot. Use is then made of asbestos or some other insulating substance to keep the heat from these hot inner walls from escaping. The heat absorbed by the inner walls must escape somehow, and since the air of the oven does not absorb it readily a great deal of it finds its

way through the walls of the oven, and the exterior wall becomes very hot, thus wasting a great deal of heat. A refractory lining for the oven would be much better than the metal one, or perhaps the metal lining would be considerably improved if it were polished so as to reflect instead of absorb the heat. Another good suggestion would be to enamel the interior of the oven with a white enamel. This would not only prevent such a large absorption of heat by the walls, but it would make the oven much lighter and more sanitary. In order to increase the artificial illumination in a room one would be foolish to paint the walls and ceilings a dull black which would absorb the light rays, but instead one would rather paint the walls some light color which would reflect the light. In heating a room or oven much the same sort of reasoning may be applied. If the walls of an oven are made so as to absorb nearly all of the thermal radiations which fall upon them, the oven will not heat nearly so well as when the walls are made so as to reflect the radiations. The heaters themselves should have a dark rough surface so as to be able to give off heat as readily as possible.

Lining for oven

Surface of heater

Electric cooking equipment

The experiments in electric cooking were carried on with the purpose of determining the cost of cooking for a family of four persons by electricity. An electric kitchen was fitted up and equipped with such apparatus from different companies as seemed to represent

best the average cooking apparatus then on the market. The equipment consisted of an oven, two six inch hot plates, one ten inch frying pan with an enamel heating element as a part of the utensil, one combination two quart cereal and vegetable cooker, one double boiler made so as to be operated on one of the hot plates, one meat broiler 10" X 14" with an enameled heating element attached, and one three pint coffee percolator.

Arrangement of apparatus

A special table was constructed for this apparatus. This table was fitted with a top of soap-stone through which the cords for the several pieces of apparatus were passed. Connectors were provided on the cords so that each piece of apparatus could be disconnected when not in use. On the front of the table were placed the switches controlling the heat on the different cords. It was not necessary to have as many cords as there were pieces of apparatus, as many of the pieces could be changed from one cord to another, and hence only as many cords need be provided as the probable maximum number of pieces of apparatus to be operated at one time.

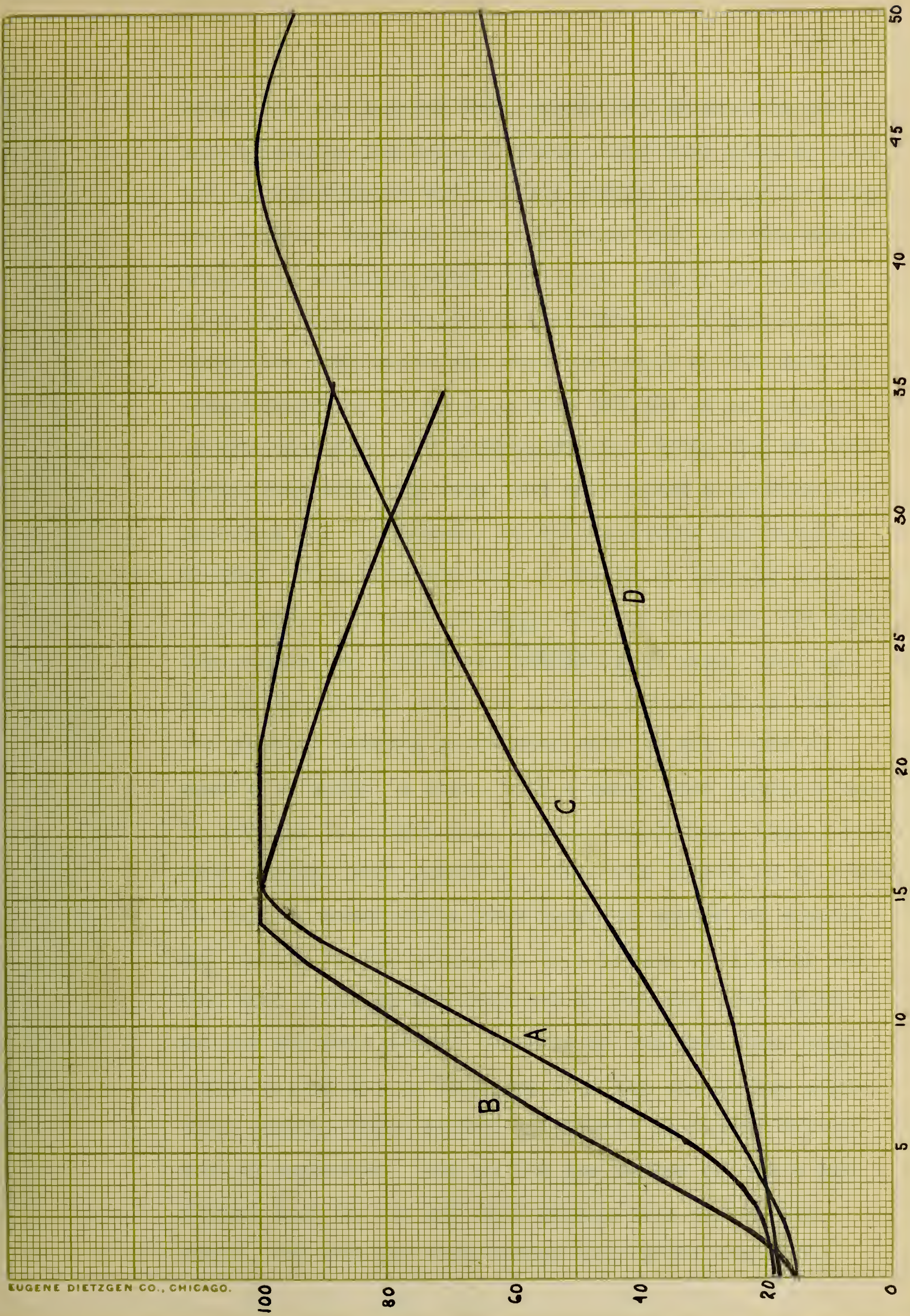
Design of oven

The oven was 19" X 12" X 13" and was equipped with two heaters, one in the bottom and the other in the top. The walls were double sheet iron and were filled in with asbestos. Two doors were provided, one made the same as the walls of the oven and the other constructed with a glass window in the center about 6" X 8". This window was constructed with two plates of rather thin

glass with an air space of 1/2" between the glasses. It was found to make practically no difference which door was used as regarded the heating of the oven. A small electric lamp was pladed inside of the oven which could be turned on by means of a convenient switch on the outside of the oven. By means of this lamp and the glass door, the cooking operations could be watched without the opening of the door. The heating elements were of the enameled grid type.

Heat capacity of stoves

In the curves on page 21 are represented some rather interesting results showing the rates of heating and cooling for different classes of electric stoves. Some electric stoves are made with the heating element imbedded in a thin piece of metal with very small capacity for the storage of heat, while other stoves are made with large heat capacities. With a stove of the former type it was found possible to heat three pints of water to the poiling point in about ten minutes, starting with the stove cold, with a consumption of only 450 watts, while with a stove of high heat capacity consumming 650 watts it was found to require 15 minutes to heat the same amount of water the same amount. It is true that part of this difference in consumption between the two stoves might be accounted for by the difference in the efficiency of the two, the 450 watt stove having its heat concentrated in the upper surface of the stove and hence not loosing so much by radiation. In


A
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EUGENE DIETZGEN CO., CHICAGO.

this test the current was turned off as soon as the water reached the boiling point. For this special case let us now compare the heating values received from the two stoves. We find from the curve that the 650 watt stove has consumed 10080 watt-min., and if we assume that the cooking temperature is 90° C. and above, we find that this stove has kept the water at the cooking temperature for 20 minutes with the use of an average of 504 watt-min. per cooking minute, while the 450 watt stove used 6272 watt-min. and maintained a cooking temperature for 10 minutes, or 627 watt-min. per cooking minute. From this and from a number of similar tests it is seen that when quick cooking is desired, the heating element of the stove should be of small heat capacity and placed near the surface of the stove, but for general cooking efficiency this is not found to amount to much. A stove with a small heat capacity can be brought to a very much higher temperature than a stove with a large heat capacity. For this reason it is found to require practically four times to amount of electrical energy to fry croquetts in a kettle of lard on the 650 watt stove as was required to fry the same amount on the 450 watt stove. Because of the fact that high temperatures may be obtained with the small heat capacity stoves, these stoves are liable to become burned out if neglected. Due to the low number of watts per square inch in the 450 watt stove, this danger was small, and for the same reason this stove was found

not to supply heat fast enough for the ordinary cooking operations. Curves C and D are taken from the same stove as B, but operated at different heats. These heats are seen to be too small to be practical for heating the utensil to the cooking temperature, but either one is found to be sufficient to maintain the cooking temperature. For water heaters the heating element should be made with as small a heat capacity as possible, as the water in this case supplies the required heat capacity.

Cost of electric cooking

It is not possible to calculate the cost of electric cooking accurately, because of the difference in cooking by different people, but in order to show something in regard to its cost the menues as shown on the following pages have been selected as representative of a series of cooking experiments carried on in the Experimental Home of the Household Science Department of the University. Here the amount of power in watt-hours required for the preparation of each meal is given, with the exception of the power used by the oven, which amount is kept seperate. From these figures it is seen to take an average of 6092 watt-hours per day, which would give 180,870 watt-hours per month, which, at a rate of five cents per killowatt-hour would make electric cooking cost $9.80 per month. Of this amount we find that the oven has consumed 108240 watt-hours, or approximately 60% of the energy was used in the oven for the baking and roasting. This result was not due

Day #1.

	Watt-hours
Breakfast Menu	725
Oat meal Sugar Cream	
Omelet	
[Baking powder Biscuits] Coffee	
-o-	
Lunch Menu	890
Cream of Tomato Soup	
Rice	
[Bread] Butter	
[Baked Apples] [Sponge Cake]	
-o-	
Dinner Menu	1045
Porterhouse steak	
[Baked Potatoes]	
[Bread] Butter	
Lettuce Salad with Mayanaise Dressing	
[Brown Betty Pudding] Lemon Sauce	
Baking	
Baked Apples	
Biscuits	
Bread	
Sponge Cake	2833
Baked potatoes	
Brown Betty pudding	1200
	6693

Day #2

	Watt-hours
Breakfast Menu	1275
Cream of Wheat	
Meat Croquetts — Fried potatoes	
Chocolate	
-o-	
Lunch Menu	1155
Tomato Soup	
Steak — Mashed potatoes	
[Bread] — Butter	
Peas	
-o-	
Dinner Menu	2700
[Rib roast] — [Baked potatoes]	
[Scalloped Corn]	
[Bread] — [Butter]	
[Orange Short Cake]	
-o-	
Baking	
Dinner cooked entirely with oven. No other baking done.	5130

Day #3

Watt-hours

Breakfast Menu — 650

Grape Fruit

Cream of Wheat   Cream   Sugar

Broiled Bacon

[Biscuits]   Coffee

-o-

Lunch Menu — 675

Meat Croquetts   [Baked Apples]

Peas

[Bread]   Butter

Cocoa

-o-

Dinner Menu — 600

Tomato Soup   Croutons

[Roast beef]   [Baked potatoes]

[Scalloped Corn]

[Bread]   Butter

Lettuce   Mayanaise Dressing

[Orange Short Cake]

Coffee

-o-

Baking

Biscuits	
Apples	
Bread	2450
Short Cake	2750
Roast	7125
Potatoes	
Croutons	
Scalloped Corn	

Day #4

	Watt-hours
Breakfast Menu	870
Cream of Wheat	
Pancakes Bacon	
Coffee	
-o-	
Lunch Menu	1350
Meat Croquetts Potato Balls	
Turnips	
[Bread] Butter	
Cocoa	
-o-	
Dinner Menu	450
[Roast Beef] Mashed Potatoes	
Peas	
[Parkerhouse Rolls] Butter	
[Pudding]	
-o-	
Baking Parkerhouse Rolls Roast Pudding	2500
	5170

to the extra large amount of baking done, but to the extremely low cooking efficiency of the particular type of oven used. There are electric ovens on the market which will give at least twice as good a cooking efficiency as the one used. This saving would then lessen the meter reading for the month from 180 kilowatt-hours to 126 which would make the expense $6.30. For certain classes of cooking electricity is found to be very economical, for example a breakfast for four or five persons can be cooked with an expenditure of not more than 1000 watt-hours. These figures show an average of about 300 watt-hours per person per meal, which result checks very well with the results obtained in actual practice. For families doing what is called light house-keeping and for flats in the large cities electric cooking is especially well adapted, and is already covering a considerable part of this field.

Heating of water

The cost of heating large quantities of water by electricity is so high compared with the cost by other means as to be almost prohibitive except in certain special cases. Both coal and gas wter heaters can be constructed which will show practically the same efficiency as an electrical equipment, and since the cost of electric energy is necessarily so much greater than the cost of other forms of energy it is seen that it is not practacal to operate an electric kitchen without a coal or gas water heater to heat large volumes of

water. For example, to heat a gallon of water from the faucet temperature to the boiling point will require 416 watt-hours at 90% efficiency, which at five cents per killowatt-hour will cost two cents.

Mr. W.S. Andrews in a discussion before the American Institute of Electrical Engineers says, "for several years past I have used electricity for cooking purposes in my home during the summer months. Water only was heated by a gas arrangement attached to the kitchen boiler, but all other heating and cooking was done by electricity at an average cost of $4.50 per month. I estimate the average cost of heating the water by gas to have been $1.50 per month, making an average total expense of $6.00 per month for cooking three meals per day for a family of four. This outlay included the heating of water for laundry and the running of an electric iron.

Advantages of electric cooking

Some of the advantages to be claimed for electric cooking may be enumerated as follows:- The most noticeable feature is the cleanliness. The entire absence of all ashes, dust, soot and burned gasses in the kitchen is an item not to be lightly considered. All of the apparatus can be nickel-plated and may be kept spotlessly clean. The apparatus may be mounted on a stone, wood or metal table, which is neat in appearance, and which is much easier to keep in a sanitary condition than a coal or gas range. All of the cooking utensils

with the exception of perhaps the oven may be made so as to be portable, and may be operated on the dining room table fully as well as on the regular cooking table in the kitchen, providing suitable connections are made in the dining room. The heat given off by the electric cooking apparatus to the air of the room is so slight as not to be noticeable, and where the comfort of the cook is to be considered, this absence of heat in the kitchen during the summer months is found to be a large factor. The heat control on all of the apparatus is definite, that is, with the switch on a certain piece of apparatus in a certain position the rate of heating will always be the same. Since there is no flame the fire risk is reduced to a minimum, and the danger from explosions is entirely done away with. Due to the absence of all fuel gasses and odors, and the fact that the heat is even, the quality of the cooking done is better than that done by other methods.

Laundry Work.

Comparative tests of gas and electric irons were made in the Urbana Steam Laundry. Eight pounds gas irons were used, and a number of seven pound electric irons of different makes. The electric irons were ordinary household irons, without any means of regulating the flow of current. For very heavy work it was found necessary to keep the switches closed on the irons the greater part of the time, but on light work it was necessary to keep turning on and off the current, which proved to be a source of considerable inconvenience. For this class of work rheostats may be purchased, by which the rate of heating may be regulated to suit the class of work being done. In the case of the gas irons it was found necessary to keep the gas turned on full all of the time, and on heavy work or when the pressure of the gas was low, the heat supplied was found to be insufficient to keep the iron up to the working temperature, and considerable time was wasted in waiting for the irons to heat. In many instances when the pressure was low they could not be made hot enough to work.

Tests made in Laundry

In order to be able to make a comparison between the gas and electric irons, as regards the amount of work done by each, careful records were kept of the time that each iron was in service, and the amount and class of work being done by each. Dry unstarched clothes such as underware, socks, etc, were not weighed, but for all

Nature of tests

of the other work, account was kept of the number of pieces, together with the weight of each both before and after ironing. On page 33 is shown a sample record sheet for one day showing the actual work done by two seven pound electric irons, and on page 34 is given the corresponding meter readings for the same irons.

Cost of operation

With gas at $1.00 per thousand cu. ft., it was found to eost on an average of about 0.5 cents per hour to operate a gas iron. The electric iron doing the same woek, consumed an average of 300 watts and operated at a cost of 1.5 cents per hour, with the electricity at 5 cents per kilowatt-hour. While the electric irons cost three times as much to operate as did the gas irons this was perhaps more than balanced by the extra amount of work done.

Saving in labor

While no definite conclusions can be drawn in regard to the saving in labor due to the use of the electric irons, due to the varying conditions, etc., it seems safe to say that 20% more work was accomplished on the average per hour with the electric irons than with the gas irons. With labor at 15 cents per hour this increase in output means, besides a general increase in the capacity of the laundry, a gross saving of three cents per hour, which gives a direct net saving over the gas irons of two cents per hour.per iron.

The heat given off by the gas irons to the air is

Form #3 Test #2

Engineering Experiment Station Univ. of Ill.

Tests of Electric Heating Apparatus

General Log Sheet - Ironing Data

Taken by W.C.M. Date 9/24/08

	Iron No.	Time on	Time off	Weight before	Weight after	No. of pieces	Class of Work
95	1	7:15	8:50				Soft goods
60	1	11:00	12:00	8	4	1	vest
				31/2	2	1	Corset cover
				5	3	1	Dress
				7	5	1	Drawers
				3	1	1	Corset covers
				10	8	1	Chemise
165	1	1:00	3:45	14	8	1	skirt
				9	6	1	waist
				5	3	1	"
				12	9	1	dress
75	2	10:45	12:00	8	4	1	apron
				13	8	1	skirt
165	2	1:00	3:45	18	12	1	coat
				18	12	1	"
				10	7	1	waist
				35	23	1	skirt

Form #2

Test #2

Engineering Experiment Station Univ. of Ill.

Ironing Data Urbana Steam Laundry

Power Record

Taken by W.C.M.

Date 9/24/08

No.	Date	Iron No.	Meter Reading	Power since last read	Time used
157	7 A.M.	1 + 2	2718.4	4.4	
	7:15 "	1			95
	11:00 "	1			60
	11:00	2			75
158	1:00P.M.	1 + 2	2720.5	2.1	165
	5:00P.M.	1 + 2	2722.5	2.0	

found to be considerable, and in warm weather causes considerable discomfort to the operators. The almost entire absence of waste heat from the electric iron is in many cases, a sufficient cause to warrent its use in laundries in preference to the gas irons.

Waste heat from irons

Electric irons were also installed in a number of private residences and very careful records kept of their performances. Here as in the laundry the consumption of the irons wss found to be from 290 to 325 watts, depending upon the design of the iron, and also upon the care with which the housewife or servant practiced economy.

Teats in private residences

Electric irons should be so designed as to have a very large heat capacity in the base of the iron. Irons made with only a thin shell of iron between the heating element and the working surface of the iron, cool too quickly when brought into contact with a very wet piece of goods, and hence while they may under test, perhaps show the highest heating efficiency, they do not always give the best satisfaction when used under the ordinary conditions of operation as do those irons having a higher heat capacity. The large heat capacity acts for the flat iron the same way as the fly wheel for the engine. It helps carry the iron over a heavy load, as for example an extra heavy wet garment. The feature of design emphasized by a great many companies is the fact that their irons heat uniformly all over the surface, or that

Design of irons

the heat is so applied as to make the point and edge of the iron hotter than the center. As a matter of fact on all work except the very heaviest, the temperature at the base of the iron is found to be practically uniform on any of the electric irons, due to the conduction of the metal. On extra heavy work it is found to be no great disadvantage to have the point and edge of the iron cooler than the center. The cool edge does not radiate heat as fast as the hot edge and hence on heavy work this form of iron often shows the higher efficiency. There are two classes of irons on the market, namely, those heated by hysteresis loss in the iron itself. The latter irons have high heat capacity in the base, and due to the fact that that the base of the iron is the heating element, there is no loss due to the transmissions of the heat through the electric insulation, which is also a good heat insulator, into the base of the iron. This iron, when suddenly cooled by a wet cloth, does not recover its heat quickly, because while the base has a high heat capacity, it does not have any large quantity of heat stored up in the heating element at high potential heat from which it may draw heat rapidly. In the resistance type of iron, the heating element is made of some material which fuses at a high temperature, and is insulated from the iron by mida or some enamel. This element usually aperates at a temperature of from 400° to 600° C. If the element has a large heat capacity it will store up considerable heat, due to the high tem-

perature, and when the iron is working light and the metal surrounding the element is suddenly cooled, the heating element is not at the same time cooled, but retains a large quantity of heat which it pours into the base of the iron very rapidly.

Calorimeter for testing efficiency of irons

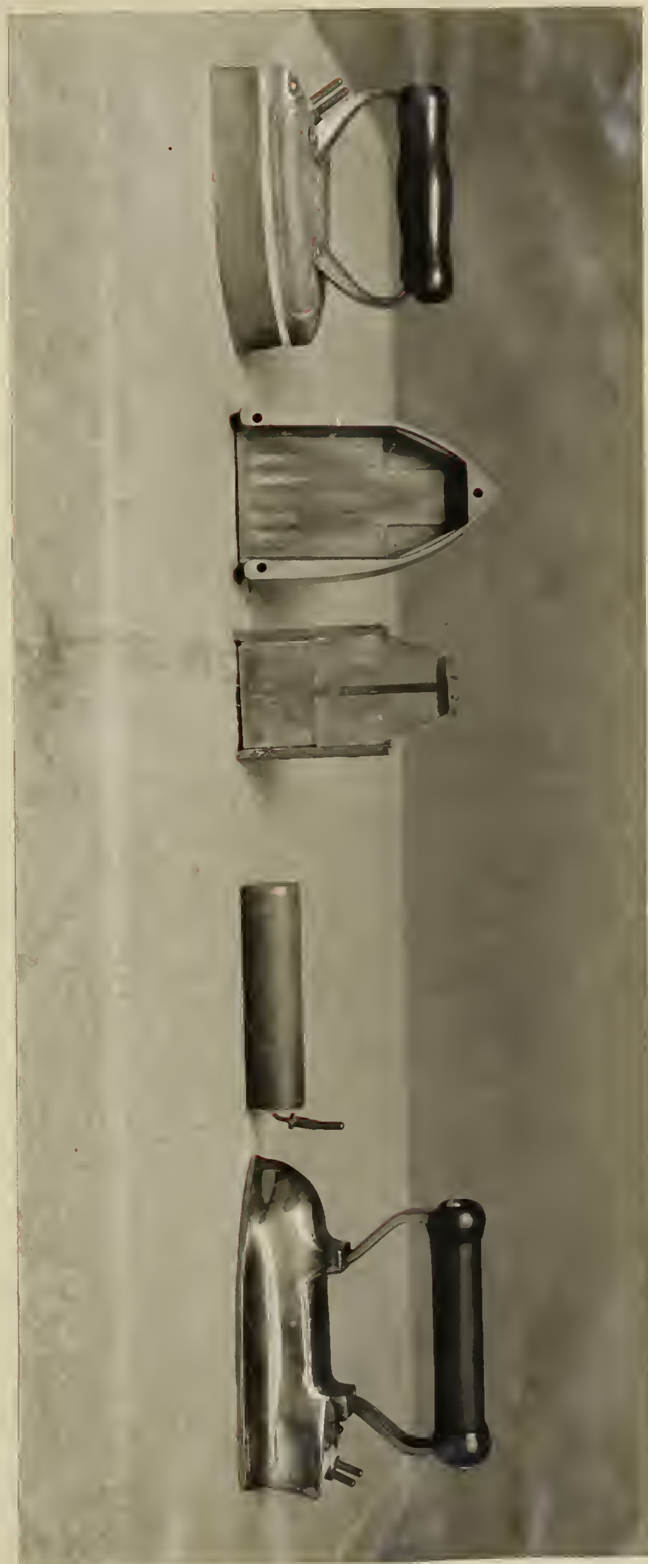
A copper calorimeter was constructed as shown in the accompaning cuts in which the irons were tested for thermal efficiency. In this calorimeter the irons were operated in their normal position, with their bases resting upon a smooth piece of copper, which in turn was cooled by the water in the calorimeter. This water was kept in circulation by means of a small fan-shaped stirer operated by an electric motor. The iron in this case was found to be kept at about its normal working temperature. All of the calorimeter was covered with asbestos on the outside and packed in a box with with mineral wool to prevent the radiation of heat as much as possible. There was some radiation of heat, however, and hence cooling curves were drawn and corrections made for all loss of heat from the calorimeter. By this method the efficiencies obtained for the various types of irons ranged from 50 to 70%. Efficiency tests were made for a period of one hour and account was taken of all of the heat received from the iron from the time the switch was closed until the iron had become cooled below the working temperature after the current was shut off.

The electric flat-iron may well be called the pio-

neer of electric household appliances. It is the first electric heating appliance to become a commercial success for domestic work and now by its general adoption, it has opened the way for the introduction of many other similar appliances which because of their convenience and labor saving qualities, are finding favor in the homes of both rich and poor.

Top View of Calorimeter

Inside Construction of Calorimeter



Summary.

Fire Risk

As regards fire risk this is practically reduced to zero by the introduction of electric heating apparatus where the wiring contractors are made to adhere strictly to the Underwriters rules. How often we see or hear of serious fires arising from overheated furnaces or kitchen ranges, defective or dirty chimney flues, or from an explosion of gas due to some one opening the valve and forgetting to apply the match until too late. Compare this with the danger of fire arising from a properly installed system of electric wiring which is nearly or quite nil.

Other electric appliances

Besides the several devises described on the previous pages, there are numerous other electrical appliances now being used daily in the homes in all of our modern cities. The first of these articles to be mentioned is the fan. In the same way that the electric sad iron is the pioneer of household electric heating apparatus the fan is likewise the pioneer of the household electric motor. Motors are now used in the home for the operation of the sewing machine, the washing machine, the vacuum cleaner and for almost every task for which mechanical power is needed, in some cases being even made to rock the cradle.

The first question asked in the consideration of any mechanical problem, nowadays, is the question of

of cost, and the question of cost is a question largely of cost of energy. Energy in some forms costs more than energy in other forms, but with the advance of science, all forms of energy are coming to be more nearly of the same value, because of the ease with which one form of energy may be changed into another form. Hence a method which shows the highest efficiency usually shows the lowest cost.

Cost of Energy

Trans-mission of heat

Heat energy cannot be stored up or transmitted from one place to another in the form of heat by any known methods without excessive losses. However, heat may be changed into electric energy, and the latter may be transmitted for long distances at comparatively slight expense.

The present prices paid for gas are not likely to be very greatly reduced. It is true that improvements are being made in the manufacture of artificial gas, and the by-products are becoming more and more valuable, but due to the nature of the process of manufacture it is bound to be wasteful and expensive. The generation of electric energy on the other hand, however, while it is now very wasteful and expensive, shows the possibility of developing to such a degree of perfection that it will be very economical. In the generation of electric energy, a grade of coal may be used which is of such a quality as to be absolutely worthless if used in the cooking range or private heating plant, also, water pow-

er in many places is available for the generation of electric energy at small cost. The greatest determining factors in the price per kilowatt-hour at the present time is the price of labor, and the interest on the investment in machinery, etc, both of which, with the present methods are capable of bery slight reduction.

Conversion factor

The present conversion factor from the heat energy of coal, when burned under perfect combustion, to electric energy may be taken as about 10%, and thus 90% of the energy is wasted in the boiler, the engine and the generator. It is possible that some method may be devised, whereby the heat of the coal may be converted directly into electric energy, and thus do away with the large losses found in the present round-about method of conversion. Even with the present methods it seems possible that the conversion efficiency may be raised from 10% to perhaps as high as 30%, and thus with the same expense for labor and fuel and the same investment, we shall be able to generate three times the amount of energy. Dynamos can now be built with an operating efficiency of 95% on full load, and the boiler with an efficiency of 80%. The steam engine is the weak spot in the whole system, showing an efficiency of only 15 to 20%. If we assume an efficiency of 20% for the engine or turbine, and 10% for the losses in the transmission of the energy from the generator to the customer, we find that 13.7% of the energy of the coal is

delivered to the customer. Hadaway in his paper on "Electric Heating"read before the American Institute of Electrical Engineers recently, made the statement that "a fair average cost of a kilowatt-hour from large central stations was 6.7 cents". A great deal of power is now sold at a rate lower than this, and for such purposes as cooking and other domestic heating uses, five cents may be assumed as a fair price. Considering the heat energy involved, this price is very high as compared with coal or gas, but when the efficiency of the electric heater is compared with that of the coal and gas heaters, we find the former to be in a class by itself, due to its high efficiency. If the cost of electric energy could, by the perfection of the steam engine, be reduced to perhaps 2.5 cents per kilowatt-hour, electricity for many domestic purposes, such as cooking and laundry work, would be found to be perhaps cheaper than either coal or gas.

Prices paid for electric energy

Standpoint of the Central Station

In considering the matter from the standpoint of the central station, we find that the electric heating load, will do a great deal toward increasing the load-factor of the plant. Since the plant must be operated for 24 hours a day, and since the heating load is found to come at such times during the day as not to interfere with the present lighting load, this heating load may be handled with a comparatively small additional expense. With the average plant the lighting load is

found to commence between the hours of five and six in the afternoon, and it is safe to say that the maximum demand per customer using electric cooking during this period will not exceed one kilowatt.

Dr. Steinmetz has made the statement, regarding a uniform load on the central station throughout the 24 hours of the day, that, "when we have accomplished that, electric power will be much cheaper than anything else, and then the end will come of gas and kerosene. And that time will come sometime, and we will probably see it".